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UNIVERSIDADE Ð COIMBRA

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Unmanned Aerial Vehicles for Healthcare and Emergency Services in Urban Airspace

Thesis proposal in the context of Informatics Engineering, advised by Professor Naghmeh Ivaki and Professor João Barata presented to the Department of Informatics Engineering of the Faculty of Sciences and Technology of the University of Coimbra.

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DEPARTAMENTO DE
ENGENHARIA INFORMÁTICA
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Abstract

In recent years, Unmanned Aerial Vehicle (UAV) technology has advanced significantly, offering potential benefits for various industries, including healthcare. However, integrating Unmanned Aerial Vehicles (UAVs) into complex, dynamic, and safety-critical healthcare systems operating within densely populated urban areas like the ones in Portugal is quite challenging. This thesis aims to bridge this gap by developing an integration framework specifically designed to Portugal's healthcare sector. By addressing key elements such as social acceptance (i.e., mainly focused on patients and healthcare workers), technical needs (i.e., types of UAVs required in diverse use cases, required software and hardware, human-UAVs interaction), and procedural adaptation (i.e., redesign the existing healthcare workflows if necessary, regulatory compliance), this framework aims to provide practical guidance for healthcare organizations and UAV manufacturers looking to employ UAVs for enhancing healthcare services.

Addressing these vital aspects, this thesis aims to prepare the way for the safe, efficient, and effective integration of UAV technology into healthcare services.

To ensure safe and compliant UAV operations in the healthcare services, it is crucial to analyze and understand the existing regulations in Portugal. Additionally, the framework will consider national and European aviation laws, particularly for urban airspace, enabling a thorough understanding of the legal framework within which healthcare-related UAV operations will take place. This initial phase will lay the foundation for the framework's development, ensuring that UAV deployments align with all relevant rules and guidelines in Portugal's healthcare systems within urban airspace.

Keywords

UAV, Unmanned Aerial Systems (UAS), Healthcare Service, Emergency Management, Medical Response, Social Acceptance, Human-UAV Interaction, Healthcare Regulations, Urban Airspace

Contents

Acronyms

AED Automated External Defibrillator.

AEDs Automated External Defibrillators.

ANAC Portuguese Civil Aviation Authority (Autoridade Nacional da Aviação Civil).

CAAI Israel Civil Aviation Authority.

CASA Australian Civil Aviation Safety Authority.

DGCA Director General of Civil Aviation.

DoD Department of Defense.

EHRs Electronic Health Records.

EMS Emergency Medical service.

FAA Federal Aviation Administration.

FEMA Federal Emergency Management Agency.

GCS Ground Control Station.

GPS Global Positioning System.

LiDAR Light Detection and Ranging.

LRS Launch and Recovery Station.

MEC Mobile Edge Computing.

MedART Medical products Aerial Transportation.

MedGRT Medical products Ground Transportation.

OHCAs out-of-hospital cardiac arrests.

ROA Remotely Operated Aircraft.

RPA Remotely Piloted Aircraft.

RPV Remotely Piloted Vehicle.

TAM Technology Acceptance Model.

UA Unmmaned Aircraft.

UAS Unmanned Aerial Systems.

UAV Unmanned Aerial Vehicle.

UAVs Unmanned Aerial Vehicles.

UTAUT Unified Theory of Acceptance and Use of Technology.

WHO World Health Organization.

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Chapter 1

Introduction

In this chapter, we discussed the integration of UAVs into the healthcare services. We also addressed the challenges presented in this context. Additionally, we outlined the problem statement, highlighting the issues that need attention and resolution. Lastly, we provided insights into the expected outcomes and contributions of this thesis proposal.

1.1 Research Context

Existing vehicles in emergency response systems, such as ambulances and helicopters, often face obstacles that prevent their efficiency and effectiveness, especially in urban areas. One of the main issues is the heavy congestion and traffic conditions, which often exist in metropolitan areas. These factors can significantly prevent the timely arrival of emergency medical services to the scene of an incident. Delays in reaching patients in critical conditions can have severe consequences, potentially impacting patient outcomes and survival rates [Lee et al., 2013]. Integrating UAVs with existing emergency systems can offer a potential solution by providing an alternative means of transportation that is not affected by ground traffic and barriers. UAVs can navigate through urban airspace more quickly, bypassing road congestion and reaching the incident site in a shorter timeframe [Khan et al., 2021]. Another problem is the limited accessibility and maneuverability of traditional emergency vehicles, such as ambulances and helicopters, in high-density areas. Urban environments are often characterized by narrow streets, high-rise buildings, and restricted landing zones. These factors can prevent the efficient movement and deployment of emergency vehicles, particularly helicopters that require suitable landing sites [Beg et al., 2021].

Additionally, the lack of real-time situational awareness can be a challenge for existing emergency systems. Ambulance crews and helicopter pilots often rely on ground-based information and visual observations to assess the situation at an incident site. This limited perspective can sometimes lead to incomplete or inaccurate assessments, potentially impacting decision-making and resource allocation. UAVs equipped with high-resolution cameras and sensors can provide

real-time aerial views and data-gathering capabilities, enhancing the situational awareness of emergency responders [Watkins et al., 2020].

Furthermore, the existing emergency systems may face difficulties in accessing certain areas, such as rooftops, high-rise buildings, or confined spaces, where patients may be located or where urgent medical supplies need to be delivered. UAVs can overcome these challenges by providing vertical transportation and aerial delivery capabilities, effectively reaching locations that are otherwise difficult to access for traditional emergency vehicles [Beg et al., 2021] [Haworth, 2016].

ultimately, the lack of efficient response times, limited accessibility in urban areas, insufficient situational awareness, and challenges in accessing certain locations are the key problems faced by existing emergency systems in urban areas. Integrating UAVs into these systems offers potential solutions by providing faster response times, increased maneuverability, improved situational awareness, and enhanced accessibility to critical areas. By implementing UAVs technology and integrating with existing medical emergency services, it is possible to address these challenges and improve the overall effectiveness and efficiency of emergency and healthcare services in urban airspace [Dandekar et al., 2021].

1.2 Problem Statement

Integration of UAVs in healthcare service represents a transformative advancement that holds great potential to revolutionize the efficiency and effectiveness of emergency healthcare [Bresciani and Potortì, 2021],[Agatz et al., 2015] .

The successful deployment of UAVs in healthcare systems and medical emergency situation relies on a combination of technology acceptance (i.e., especially by patients and healthcare workers), technical implementation (i.e., appropriate UAVs for diverse use cases, and required hardware and software), and procedural adaptation (i.e., redesign of the existing healthcare workflow if necessary and regulatory compliance).

Regarding technology acceptance, healthcare professionals and stakeholders need to be educated and trained on UAV operations and their potential benefits in patient care, emergency response, and medical delivery. Many healthcare professionals may not be familiar with operating or trusting these autonomous systems in critical medical scenarios. The lack of awareness and training on UAVs can lead to unwillingness in adopting this technology for tasks like medical supply deliveries or remote patient monitoring. Additionally technology should be user-friendly and intuitive to encourage its adoption in health.

Regarding technical implementation, it's crucial to select the appropriate category of UAVs to ensure they align perfectly with the specific needs of medical tasks and applications. First challenges related to the development of specialized UAV models fit to healthcare applications. Additionally, another technical challenge is establishing a reliable communication infrastructure is vital to facilitate real-time data transmission between the UAV and health services. These sys-

tems must be reliable in remote and challenging environments, such as disaster-stricken areas or remote clinics. Final challenge is continuous monitoring, maintenance, and regular updates of UAV systems that are necessary to guarantee their operation in the dynamic healthcare environment.

Finally, Regarding procedural adoption, deploying UAVs in the healthcare sector necessitates a comprehensive approach. First, it requires the establishment of clear operational protocols and guidelines that encompass flight safety, data collection, and privacy concerns. This lack of clear procedural frameworks creates confusion and uncertainty among healthcare professionals and administrators, preventing the efficient and effective use of UAVs. Additionally, healthcare staff and stakeholders need to be adequately trained to operate and manage UAVs effectively, ensuring that the technology is integrated into existing healthcare workflows. There is a significant gap in the knowledge and skills required to maximize the benefits of UAVs. Bridging this knowledge gap and fostering acceptance among healthcare workers is crucial for the successful integration of UAVs into healthcare workflows. Moreover, regulatory compliance and adherence to legal requirements are crucial to ensuring the lawful and ethical use of UAVs in healthcare settings. Lastly, ongoing monitoring and evaluation of UAV deployments are essential to identify areas for improvement and optimize their utility in providing timely and efficient healthcare services.

1.3 Expected Contributions

This study aims to explore the integration of UAVs in healthcare and medical emergency situations within an urban area. The primary objective is to develop an integration framework to help the implementation and deployment of UAV-based healthcare systems that effectively improve emergency response and healthcare services in urban environments. The main contributions expected from this PhD thesis are as follows:

- **A mapping between different UAV models for specific medical use cases:** This mapping will serve as a resource for healthcare professionals and organizations looking to deploy UAVs in various healthcare scenarios. By categorizing UAV models based on their capabilities, payload capacity, flight range, and other technical specifications, healthcare decision-makers can make more informed choices about which UAVs are best suited for tasks such as medical supply delivery, telemedicine, hospital internal delivery, or patient monitoring.

- **A UAV acceptance model in healthcare and medical emergency:** This model customized to meet the unique needs of healthcare and medical emergency situations. it will not only enhance emergency response capabilities but also contribute to improved patient care, resource efficiency, and the responsible adoption of UAV technology in the healthcare services.

- **Development of an Integration Framework:** A structured framework that

outlines the essential components, processes, and considerations for combining the UAV technology into the healthcare services.

- **An evaluation and validation platform:** The development of a testing platform that can simulate scenarios integrating UAVs in medical use cases in different circumstances.

1.4 Proposal Outline

This thesis proposal comprises six distinct chapters, each serving a specific purpose. In Chapter 1, the focus centers on presenting the problem statement and outlining the expected outcomes of the study. Moving on to Chapter 2, an in-depth background is provided, covering topics such as UAVs, Emergency Management Services, Technology Acceptance, Healthcare Services, and an overarching overview of the application of UAVs in Emergency Services and Healthcare. Chapter 3 delves into the state-of-the-art potential of UAVs within the domains of emergency services and healthcare. Chapter 4 is dedicated the objectives of this thesis project, while Chapter 5 presents the methodology employed in this undertaking. Lastly, Chapter 6 serves as a conclusions.

Chapter 2

Background

In recent years, Unmanned Aerial Vehicles (UAVs), commonly known as drone, have rapidly emerged as a new technology. As the technology continues to grow, stakeholders in healthcare and emergency management sectors are becoming increasingly aware of the benefits UAVs can bring to their operations. UAVs offer a cost-effective, efficient, and versatile solution to tackle numerous challenges faced in both healthcare and medical emergency scenarios. However, adopting technologies also has challenges, particularly in safety-critical sectors like healthcare. This section provides an overview of the relevant background information for this thesis proposal. It includes the following fundamental topics: 1) UAVs and Unmanned Aerial Systems (UAS), 2) utilization of UAVs in healthcare services, 3) healthcare services, 4) emergency management systems, and finally 5) technology acceptance.

2.1 Unmanned Aerial Vehicle (UAV) and Unmanned Aerial System (UAS)

UAVs are vehicles that fly without a human on board. Alternative terms include Remotely Piloted Aircraft (RPA), the term preferred by the military Authorities, as well as Unmmaned Aircraft (UA), Remotely Piloted Vehicle (RPV), and Remotely Operated Aircraft (ROA). The Unmanned Aerial Vehicle (UAV) is an essential component of the Unmanned Aerial System (UAS), which comprises a communication link and a ground control station as well. By surpassing the limitations of terrestrial systems in accessibility, speed, and reliability, the UAV plays a crucial role. Its capabilities include delivering cloud-free, high-resolution images, making it valuable in various commercial applications like agriculture, mining, monitoring for missing persons, and assessing disaster-stricken areas. Originally designed for defense purposes, including reconnaissance and combat, the UAV has evolved into a versatile and essential tool [Krey and Seiler, 2019a].

2.1.1 UAVs Characterization

In the last decade, there has been significant growth in the development of UAVs, and it is expected that by 2027, the global UAV production market will exceed 2.3 billion dollars [Fawaz et al., 2017]. Recently, UAVs have received considerable attention due to their logistical, inspection, and monitoring potential. Over the past decade, there has been significant growth in the commercial UAV industry. According to the 2019 Drone Market Report by Drone Industry Insights, it is projected that the sales of commercial UAVs will continue to rise, with India expected to emerge as the third-largest market for commercial UAVs by the year 2024 [Schroth, 2019]. Drone-based communication systems play a crucial role in this expanding industry, offering two primary modes of communication: air-to-ground (communication with a base station) and air-to-air (communication with other UAVs). Nevertheless, the use of UAVs is controlled by regulatory restrictions so that the population is protected and facilitates their acceptance for other purposes [Watkins et al., 2020].

The improvement of materials, as well as the creation of detection and coordination algorithms and a regulatory framework aligned with technological advances in manufacturing, enable the creation of a wide range of UAVs of different sizes and weights, capable of being used on a large scale, including in situations where human presence is impossible [Chauhan et al., 2019],[Hassanalian and Abdelkefi, 2017]. To decide which UAV type should be used for a given use case, the nature of the use case must be considered. For instance, in cases where transport is required to be slow, a multi-engine vehicle should be used, as it has better stability and allows maneuvers in tight spaces, making it advantageous in urban areas with tall buildings. On the other hand, fixed-wing models are more suitable for carrying larger payloads at higher speeds and over greater distances. UAVs used to deliver orders are usually battery-powered, have a maximum load capacity of 5 kg, and have a maximum flight distance of around 50 km at a speed varying between 15 and 65 km/h, reaching a maximum altitude of 30 to 120 meters. In addition, for the UAV to unload the package, 2 m^2 of landing space is required [Beloev, 2016].

2.1.2 Classification of UAVs

For any mission assigned to a UAV, its life cycle always consists of taking off from a base, visiting defined targets, and returning to that base. Since these aircrafts do not require a pilot, their weight will reduce, and consequently, their energy consumption will reduce as well because the cockpit and the environmental systems, which provide air, thermal control, and pressurization of the cabin, are no longer necessary [Savuran and Karakaya, 2017].

Recent advancements in UAV technology and related technologies have opened up new opportunities for various commercial applications. However, depending on the specific application or use case, UAVs of various types can be used. In general, UAVs can be classified based on their size, range, endurance, number of rotors, and altitude, as shown in Figure 2.1 [Ganesan et al., 2020]. Here we

present an overview of how UAVs are categorized based on these factors:

1. **Classification Based on Size**

   - **Micro UAVs:** These are the smallest UAVs, typically weighing less than 250 grams and having a wingspan of less than 50 centimeters (20 inches). Micro UAVs are often used for indoor applications, close-range surveillance, and consumer photography.
   - **Mini UAVs:** Mini UAVs are slightly larger, with a wingspan ranging from 50 centimeters to 2 meters. They are commonly used for recreational purposes, aerial photography, and short-range reconnaissance.
   - **Medium UAVs:** Medium-sized UAVs typically have a wingspan between 5 meters and 10 meters. They are used for a wide range of applications, including environmental monitoring, search and rescue, and cargo delivery.
   - **Large UAVs:** Large UAVs have a wingspan exceeding 15 meters. These UAVs are often used for long-range surveillance, military reconnaissance, and cargo transport.

2. **Classification Based on Range**

   - **Short-Range:** Short-range UAVs have a limited operational range, typically up to a few kilometers. They are suitable for applications where the UAV does not need to cover long distances.
   - **Medium-Range:** Medium-range UAVs can operate at distances, ranging from several kilometers to tens of kilometers. They are commonly used for tasks like pipeline inspection and wildlife monitoring.
   - **Long-Range:** Long-range UAVs are designed to cover extensive distances, often exceeding 100 kilometers. They are used for missions such as border surveillance and ocean monitoring.

3. **Classification Based on the Number of Rotor**

   - **Fixed-Wing:** Fixed-wing UAVs have wings like traditional airplanes and rely on aerodynamic lift for flight. They are known for their endurance and are suitable for mapping, surveillance, and cargo transport.
   - **Multirotor:** Multirotor UAVs, such as quadcopters (four rotors), hexacopters (six rotors), and octocopters (eight rotors), are highly maneuverable and can hover in place. They are commonly used for aerial photography, surveillance, and short-range tasks.

4. **Classification Based on Altitude**

   - **Low-Altitude:** Low-altitude UAVs typically operate at altitudes below 500 meters above ground level (AGL). They are well-suited for tasks like monitoring crops, wildlife, and urban areas.

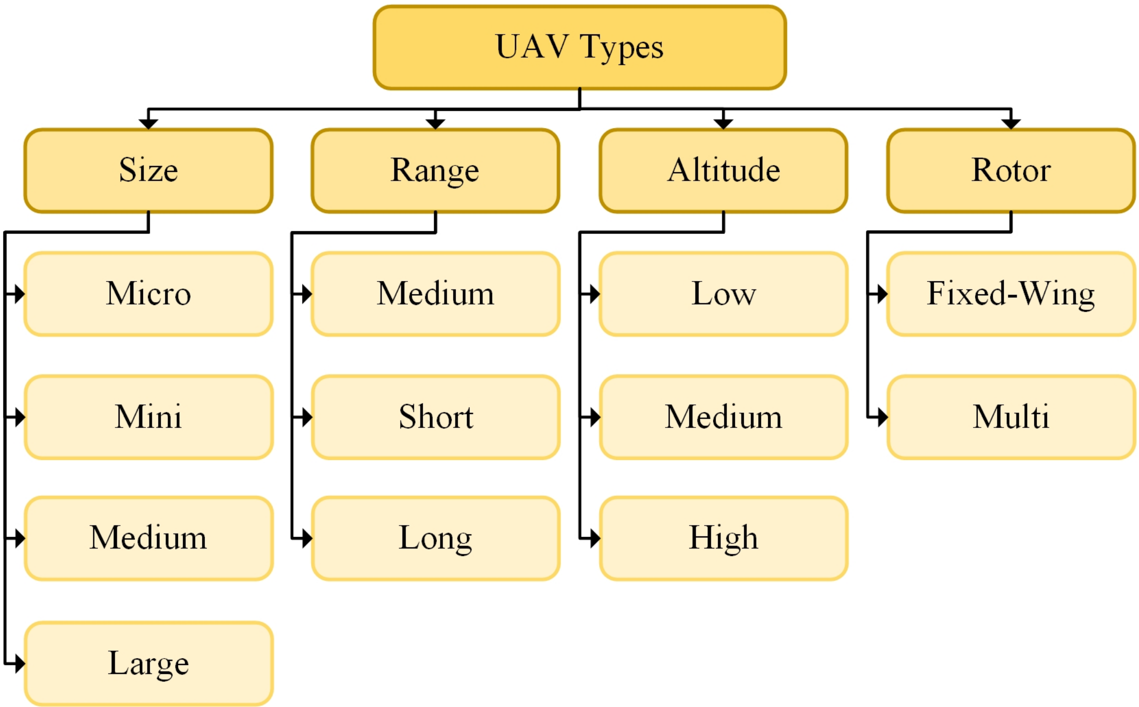

Figure 2.1: Classification of UAVs based on Size, Range, Number of Rotors and Altitude [Ganesan et al., 2020]

- **Medium-Altitude:** Medium-altitude UAVs can operate at altitudes, ranging from 500 meters AGL to several kilometers. They find applications in environmental monitoring, weather research, and border surveillance.
- **High-Altitude:** High-altitude UAVs are capable of flying at altitudes exceeding several kilometers, often reaching the stratosphere. These UAVs are used for tasks like atmospheric research, telecommunications, and long-range surveillance.

Singhal at. el. classified UAV based on landing and takeoff, aerodynamics, and multi-rotors, as shown in Figure 2.2 [Singhal et al., 2018].

1. **Classification Based on Aerodynamics-Based:** The performance of an aircraft in flight is influenced by four fundamental forces: lift, weight, thrust, and drag. To optimize UAV performance across various conditions, the classification was based on the type of aircraft wing. This classification encompasses four main categories:

    - Fixed Wing UAVs: These UAVs have static, non-moving wings similar to traditional airplanes. They are designed for efficient, long-range flight and are well-suited for applications such as mapping and surveillance.
    - Flapping Wing UAVs: These UAVs mimic the flapping motion of birds or insects. Their wing design enables unique maneuverability and is often used for specialized tasks like biomimicry research.

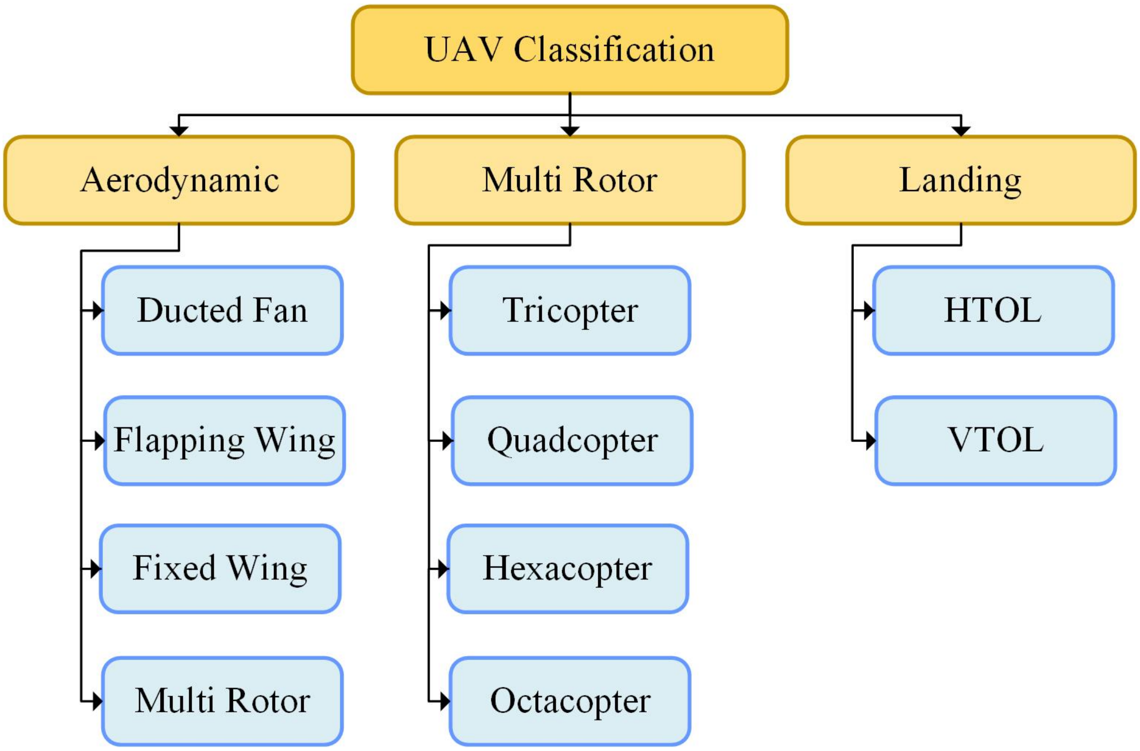

Figure 2.2: Classification of UAV based on landing and Take off, Aerodynamic and Multi-Rotor [Singhal et al., 2018]

- Multirotor UAVs: Multirotor UAVs feature multiple rotors, typically in the form of quadcopters (four rotors), hexacopters (six rotors), or octocopters (eight rotors). They are known for their stability, vertical take-off and landing (VTOL) capabilities, and are commonly used in aerial photography, surveillance, and short-range missions.
- Ducted Fan UAVs: Ducted fan UAVs have enclosed rotor systems, which offer improved safety and efficiency. They are used in applications requiring precise control, such as indoor inspections and research.

2. **Classification Based on Takeoff and Landing capabilities:** When categorizing UAVs based on their takeoff and landing capabilities, the focus is on how the UAV initiates and concludes its flights. Consequently, this classification divides UAVs into two distinct categories:

   - UAVs with Horizontal Takeoff and Landing (HTOL) capability
   - UAVs with Vertical Takeoff and Landing (VTOL) capability

3. **Classification Based on Weight and Range:** Table 2.1 shows this classification of UAVs that considers the maximum weight and maximum range of UAVs as factors to classify.

Table 2.1: List of UAVs based on Weight and Range [Singhal et al., 2018]

Type	Maximum Weight	Maximum Range	Category
Nano	200 gms	5 Km	Fixed Wing, Multirotor
Miro	2 Kg	25 Km	Fixed Wing, Multirotor
Mini	20 Kg	40 Km	Fixed Wing, Multirotor
Light	50 Kg	70 Km	Fixed Wing, Multirotor
Small	150 Kg	150 Km	Fixed Wing
Tactical	600 Kg	150 Km	Fixed Wing
MALE	1000 Kg	200 Km	Fixed Wing
HALE	1000 Kg	250 Km	Fixed Wing
Heavy	2000 Kg	1000 Km	Fixed Wing
Super Heavy	2500 Kg	1500 Km	Fixed Wing

2.1.3 UAVs Applications

Once confined to military applications, UAVs are now gaining widespread adoption in the commercial sector, particularly in last-mile deliveries in logistics operations. UAVs are able to carry out missions both outdoors and in closed spaces in civil areas [Hassanalian and Abdelkefi, 2017]. UAVs have also revolutionized environmental monitoring across various domains, offering efficient and cost-effective solutions to gather critical data for air, soil, crop, water, underwater, and mountain monitoring [Arnold et al., 2013]. Furthermore, UAVs have transformed defense and military operations by offering a wide range of applications that enhance surveillance, intelligence gathering, and combat capabilities.

Figure 2.3 illustrates the potential applications of UAVs in the civil, environmental, and defense domains presented in [Singhal et al., 2018].

The most common UAV applications in Civil areas are as follows:

- Healthcare: In medical care applications, UAVs are being utilized to overcome logistical challenges, improve response times, and deliver critical supplies to remote and inaccessible areas. For instance, in emergency situations, UAVs equipped with medical kits can swiftly transport life-saving equipment, such as defibrillators or emergency medications, to accident scenes or remote locations, ensuring timely intervention and potentially saving lives. Moreover, UAVs are being utilized to address the challenges of delivering medical supplies to underserved areas with limited infrastructure. The UAVs can transport vaccines, medicines, blood samples, and diagnostic equipment to remote communities or disaster-affected regions where existing transportation methods face obstacles [Soni and Saravanan, 2021]. Furthermore UAV is crucial for telemedicine, where it assist in connecting patients with doctors and healthcare providers from a distance. They can also be seen working as robotic arms, aiding surgeons in delicate and precise procedures [of Seville, 2017]. Additionally, these UAVs are playing a crucial role in the internal logistics of hospitals by facilitating the efficient delivery of essential supplies and medications within the hospital premises

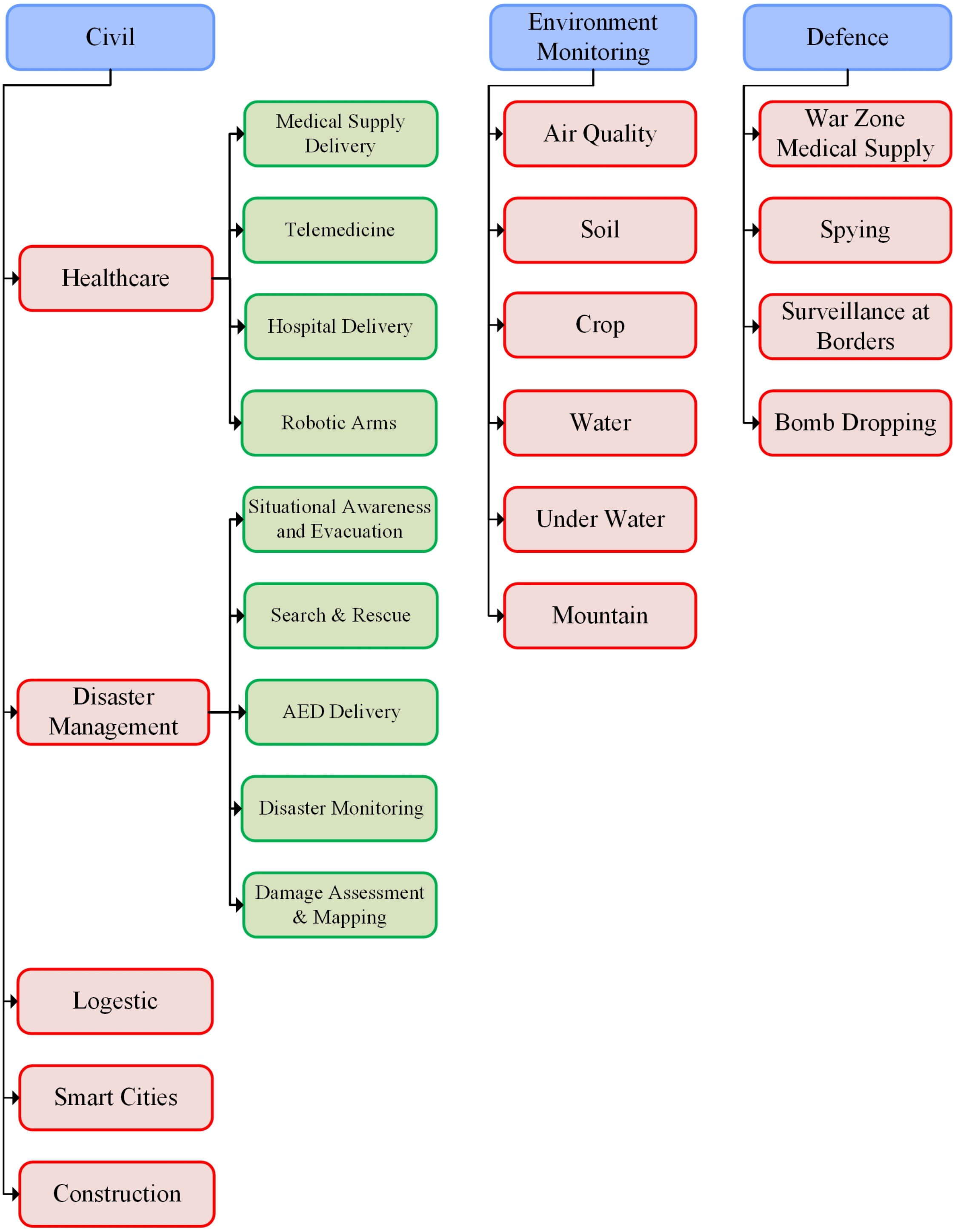

Figure 2.3: Potential Application of UAV [Singhal et al., 2018]

[Sharma et al., 2023].

- Disaster Management: UAVs have emerged as invaluable tools in disaster management, significantly enhancing various aspects of response and recovery efforts. One crucial application is the enhancement of situational awareness [Van Tilburg, 2017]. UAVs equipped with high-resolution cameras and thermal imaging capabilities can quickly provide real-time aerial views of disaster-affected areas, allowing first responders and emergency personnel to assess the extent of damage and identify areas in need of immediate attention. This rapid situational awareness helps in making informed decisions, coordinating resources effectively, and prioritizing rescue operations. Additionally, UAVs can aid in the efficient deployment of search and rescue teams by providing aerial guidance, especially in hard-to-reach or hazardous locations [Chowdhury et al., 2017]. Automated External Defibrillator (AED) delivery by UAVs is another critical application in disaster scenarios. In situations where quick access to medical equipment can be a matter of life and death, UAVs can be dispatched to deliver AED to the scene of cardiac emergencies. These UAVs can be equipped with GPS and communication systems, allowing dispatchers to guide them to precise locations [Cheskes et al., 2020]. Furthermore Thermal imaging cameras and advanced sensors can help locate heat signatures, making it easier for rescue teams to identify and save lives in time-critical scenarios [Hassanalian and Abdelkefi, 2017].

- Logistic: In logistics and transport, UAVs are used to transport and deliver cargo. In 2013, appropriate technologies were developed for UAVs, which aimed to promote safe, fast, and ecological transport. Thus, UAVs started to be used for delivering urgent medicines and other common goods to areas with difficult access [Beloev, 2016]. In urban environments, there is greater proximity of UAVs to buildings, which implies that the speeds are lower since there is a greater degree of disorder, whether due to the presence of vegetation, wires, power poles, buildings of various sizes, cars, other UAVs, or people [Baumgarten et al., 2022]. Therefore, in order to combat the urban movement, possible landings on top of buildings or deliveries on each level of the building are already being studied, leading to the possible creation of landing stations dedicated to this purpose. In contrast, suburban deliveries are likely to work better, but they continue to be challenging due to the presence of animals in the gardens, theft, or the noise they cause [Watkins et al., 2020].

- Smart Cities and Smart Homes: The urban landscape is ready to witness a substantial influx of dynamically connected devices driven by various activities. UAVs as mobile vehicles are anticipated to play crucial roles, encompassing real-time traffic control, transportation, infrastructure management, and building observation [Gera et al., 2021]. Consequently, UAVs are expected to enhance the smart cities by offering communication services to diverse smart devices in urban areas, thereby enriching the application perspective. Additionally, UAVs have proven useful in contexts like lightweight parts delivery within manufacturing plants, where Global Posi-

tioning System (GPS) was inadequate for indoor positioning, along with applications in intelligent shipping, monitoring, and control [Munawar et al., 2022].

- Construction: UAV-enabled Mobile Edge Computing (MEC) and computer vision techniques are promising solutions for the condition assessment of civilian and public infrastructures [Restas, 2015]. UAVs are being used increasingly in many construction tasks, such as building inspections, building condition monitoring, damage assessments of buildings after disasters, public site surveying and mapping, safety inspections of construction sites and workers, and monitoring the progress of construction [Tatham, 2009].

The most common UAV applications in environmental monitoring are as follows:

- Air Quality monitoring: One of the significant advantages of UAV-based air quality monitoring is its versatility. These UAVs can be deployed for both routine monitoring and emergency response situations. For instance, during wildfires or industrial accidents, UAVs can rapidly assess the spread of pollutants and the potential health risks to communities, allowing authorities to take timely action. Moreover, the integration of artificial intelligence and machine learning algorithms enables UAVs to process vast amounts of data and produce accurate pollution maps, assisting in identifying pollution sources and formulating effective pollution control strategies [Gu and Jia, 2019].

- Soil monitoring: In soil monitoring, UAVs equipped with specialized sensors can assess soil quality, moisture content, and nutrient levels with high precision. This data helps farmers optimize their irrigation and fertilization practices, leading to increased crop yields and reduced environmental impact. Moreover, UAVs enable real-time monitoring, allowing for early detection of soil erosion and pollution, thereby contributing to sustainable land management practices [d'Oleire Oltmanns et al., 2012].

- Crop monitoring: In crop monitoring, UAVs provide invaluable support to agriculture by monitoring crop health and growth patterns. Multispectral and thermal cameras onboard UAVs can capture detailed imagery that helps farmers identify areas of stress, disease outbreaks, or nutrient deficiencies. By detecting these issues early, farmers can take targeted actions, such as adjusting irrigation or applying pesticides sparingly, resulting in reduced costs and minimized environmental harm. Additionally, UAVs offer rapid coverage of large agricultural areas, making crop monitoring more efficient and accessible for farmers of all scales [Amarasingam et al., 2022].

- Water monitoring: Water monitoring is another critical application where UAVs shine. These flying platforms equipped with various sensors can assess water quality, detect pollutants, and monitor changes in water bodies such as rivers, lakes, and reservoirs. In remote or hard-to-reach areas, UAVs can provide valuable data on water sources and ecosystems, aiding in the early detection of contamination events or illegal activities [Zang et al., 2021].

- Underwater monitoring: Underwater UAVs enable the exploration and monitoring of aquatic ecosystems and underwater infrastructure, including pipelines and shipwrecks. This technology has vast applications in marine biology, environmental research, and infrastructure maintenance [Zang et al., 2021].
- Mountain monitoring: In mountain monitoring, UAVs equipped with high-resolution cameras and Light Detection and Ranging (LiDAR) sensors can capture detailed topographic data and create accurate 3D models of mountainous terrain. This data is crucial for assessing landslide risks, tracking glacial changes, and planning infrastructure development in rugged landscapes [Wu et al., 2019].

The most common UAV applications in defense are as follows:

- War zone Medical Supply: War zone medical supply missions utilizing UAVs have revolutionized humanitarian efforts by significantly reducing response times and improving the overall efficiency of healthcare delivery. These UAVs can transport essential medical equipment, such as blood, vaccines, first-aid supplies, and even organs for transplantation, quickly and safely. Moreover, their ability to operate autonomously or under remote human supervision enables humanitarian organizations and medical teams to reach isolated and conflict-stricken regions, ultimately saving countless lives by ensuring that critical medical care is provided promptly when it is needed most [Braun et al., 2019].
- Spying: One of the most well-known uses of UAVs in defense is in the realm of intelligence and spying [Ma'Sum et al., 2013]. UAVs equipped with high-resolution cameras and advanced sensors can perform reconnaissance missions deep within enemy territory without putting human assets at risk. These spy UAVs can capture vital information, monitor enemy movements, and assess potential threats, providing crucial data for strategic decision-making [Utsav et al., 2021].
- Surveillance at Borders: In addition to intelligence gathering, UAVs play a significant role in border security and surveillance. Many countries use UAVs to monitor their borders, helping to detect illegal border crossings, smuggling activities, and other security threats. UAVs equipped with thermal imaging cameras and advanced tracking systems can operate day and night, providing real-time data to border patrol teams. This not only increases the efficiency of border surveillance but also improves response times to potential threats, enhancing overall border security.
- Bomb Dropping: Moreover, UAVs have been adapted for offensive purposes, such as bomb dropping or precision strikes. These combat UAVs can carry and deploy various munitions, including guided missiles and precision-guided bombs [Xiaoning, 2020].

In addition to these applications, we can find personal UAVs taking aerial photographs during events or even making footage that is incorporated into films

and advertisements, among others. Moreover, due to technological advances in electronics and sensors, the scope of UAVs applications has increased, now supporting traffic monitoring and remote sensing activities[1] [Fawaz et al., 2017]. When containing sensors, UAVs can be used to capture multi-sensory information that allows overlapping temporal information of various types, making it possible to build a time frame of evolution [Watkins et al., 2020].

2.1.4 Advantages of Using UAVs

As mentioned earlier, the application of UAVs is quite wide. They offer a multitude of advantages in the fields of healthcare and medical emergency management, where timely and accurate information is critical for saving lives and providing effective care. One of the primary advantages of using UAVs in emergency management is their ability to provide rapid response and assessment capabilities. In the event of a disaster or crisis, UAVs can be deployed quickly to survey affected areas, assess damage, and identify hazards [Yoo et al., 2017]. This real-time aerial view allows medical emergency responders to make informed decisions and allocate resources more efficiently [Tiwapat et al., 2018].

UAVs equipped with advanced sensors and imaging technology can provide unparalleled situational awareness. They can capture high-resolution images, collect thermal data, and even perform multispectral analysis, enabling responders to understand the extent of a crisis better or assess the condition of patients remotely. In disaster scenarios, this information helps emergency management teams strategize their efforts effectively. In healthcare,UAVs can facilitate remote patient monitoring, allowing healthcare providers to assess vital signs and patient conditions from a distance, particularly useful in situations where immediate access to medical facilities is limited [Aurambout et al., 2019].

UAVs can access hard-to-reach or hazardous areas without risking human lives. They also eliminate the need for expensive manned aircraft or ground vehicles in specific scenarios. For example, UAVs can search for survivors in dangerous locations, reducing the risk to search and rescue teams. UAVs also can transport medical samples or supplies to remote or underserved areas more efficiently than traditional methods, saving both time and money [Scott and Scott, 2021].

2.1.5 Limitation of Using UAVs

Using UAVs in the commercial sector has some limitations, which must be considered when planning operations, which are not part of traditional means of transport. One of the current limitations concerns battery autonomy, which impacts resistance and flight duration, affecting the speed and the payload to be transported [Murray and Chu, 2015]. Currently, the battery with the highest energy density is 220 Wh/kg, which represents less than 2 percent of the value of fossil fuels and a maximum flight time of 40 minutes [Watkins et al., 2020].

[1] remote sensing technologies involve collecting information or data about the Earth's surface or other objects from a distance

Moreover, the size of the UAVs will limit the dimensions of the package it can carry. Thus, the UAV must return to the starting point after making the delivery or have several UAVs allocated to the same task to satisfy the demand when it is impossible to combine more than one package due to their sizes. The maximum payload allowed is dependent on the motor power, the size and number of propellers, the type of battery, and the weight of the UAV [Agatz et al., 2015]. Additionally, the range of a UAV depends on the load it carries. Thus, the greater the load, the smaller the range, which requires the existence of more deposits distributed throughout the region [Tiwapat et al., 2018].

Furthermore, unexpected and/or adverse weather conditions vary the energy consumption and, consequently, the range of the UAV. The smaller size, mass, and flight speed of the aircraft, the more fragile it becomes, making it more challenging to operate at windy heights [Watkins et al., 2020]. The collision with another aircraft or with another moving object, as well as the possible impact with people or structures located on the ground, are risks that arise from the use of UAVs, which reduce the response capacity and make urban navigation complicated [Watkins et al., 2020].

Another concern that arises when using UAVs is related to Inappropriate use since they can be considered abusive regarding privacy and security. As such, the American organization Federal Aviation Administration (FAA) has strict restrictions that limit the use of UAVs for commercial activities. Additionally, they are also involved in crimes, such as the delivery of contraband and prisoners, firearms, terrorism, and even hacking [Scott and Scott, 2021].

2.1.6 Unmanned Aerial System (UAS)

The design of the UAS includes the unmanned aerial vehicle and other subsystems, which include the communication link between the UAV and the user, the ground control station, and the payload. The design of UAV integrates the parts evolving from the vehicle frame to complete the ready-to-fly aerial vehicle. The selection of components like the airframe, controller, motor, propellers, and power supply is a crucial task that requires in-depth knowledge and full-fledged mathematical calculations to design a UAV for a specified mission. Figure 2.4 shows the subsystems and modules for the design of UAS [Y. et al., 2021].

The US Department of Defense (DoD) defines UAS as a system that includes UAV, Ground Control Station (GCS), Launch and Recovery Station (LRS), Datalink, Payload, Human Interface, and Technical Support System [Ramesh, 2022]Each subsystem plays a critical role. The collective capabilities and constraints of the UAS are determined by these individual components. Considering the comprehensive nature of the contemporary unmanned system, "drone" may not be the most suitable term to represent it. Instead, UAS encompasses all the subsystems under one umbrella, as shown in Figure 2.5 [Ramesh, 2022]. The following six key components are crucial for the functionality and mission success of a UAS:

- **Data Link:** The Data Link subsystem is responsible for establishing and

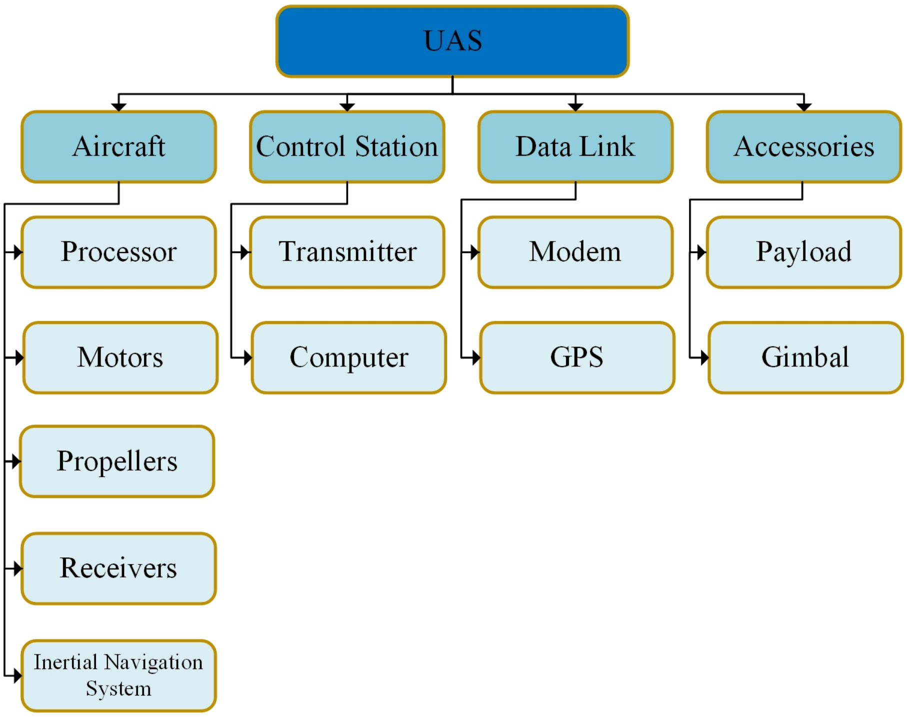

Figure 2.4: Unmanned Aerial System Subsystems [Y. et al., 2021]

maintaining communication between the UAV and its GCS. It enables the transfer of real-time data, including telemetry information, sensor data, and mission commands. The reliability and security of the data link are essential to ensure uninterrupted communication during the UAS's flight.

- **Payload:** The Payload subsystem encompasses the sensors, cameras, and other equipment attached to the UAS. Payloads vary depending on the mission's objectives and can include high-resolution cameras, thermal imaging sensors, LiDAR scanners, or even specialized equipment like magnetometers or radiation detectors. The payload is critical for data collection and analysis, making it a core component of the UAS.

- **Ground Control Station (GCS):** The Ground Control Station serves as the central hub for UAS operation. It provides the human operator with the tools to plan, execute, and monitor the mission. The GCS typically includes software for mission planning, flight control, and real-time data analysis. Operators use the GCS to control the UAV's flight path, monitor sensor data, and make critical decisions during the mission.

- **Launch and Recovery System (LRS):** The Launch and Recovery System is responsible for safely launching and recovering the UAS. Depending on the UAS type, this subsystem may involve catapults, launch rails, nets, or automated landing systems. Ensuring a reliable LRS is essential for mission success, especially in challenging environments or when launching from moving platforms.

- **Human Interface:** The Human Interface subsystem is designed to facilitate effective communication between the human operator and the UAS. It in-

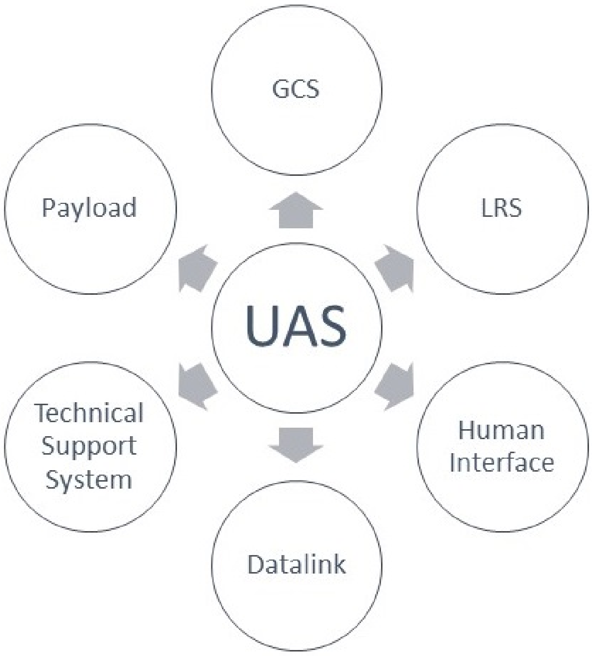

Figure 2.5: UAS Subsystems [Ramesh, 2022]

cludes the user interface on the GCS, which provides real-time feedback on the UAS's status, sensor data, and mission progress. A user-friendly interface is crucial to ensure that operators can make informed decisions quickly and efficiently.

- **Technical Support System:** The Technical Support System encompasses maintenance, repair, and logistics support for the UAS. This includes spare parts, tools, maintenance procedures, and personnel training. Ensuring that the UAS is well-maintained and can be quickly repaired in the field is vital for minimizing downtime and ensuring mission readiness.

2.1.7 UAS Operation and Regulation

The use of UAS have increased in recent years, prompting governments worldwide to establish regulations to ensure safe and responsible UAV operations. These regulations vary from one country to another but generally cover key aspects of UAV operation, including registration, pilot certification, flight restrictions, safety guidelines, and privacy concerns. This Regulation restates comprehensive provisions governing the operation of UAS, as well as the roles and responsibilities of personnel involved in these operations, encompassing remote pilots and associated organizations. Three categories of UAS operations are as follows [2019/947-SKYbrary, 2019]:

- **Open:** These operations do not necessitate any prior operational authorization or a declaration by the UAS operator before the operation occurs.

- **Specific:** These operations require authorization from the competent authority or a declaration by the UAS operator.

- **Certified:** These operations necessitate the UAS to be certified according to Delegated Regulation (EU) 2019/945, along with the certification of the operator and, if applicable, the licensing of the remote pilot.

The **Open** category is further split into 5 classes (C0, C1, C2, C3, and C4) based on size, weight (including payload), speed, and other requirements (e.g., lights, presence of the geo-awareness system, contents of the User manual, etc.). The maximum take-off mass of this category is less than 25 kg (classes C3 and C4). UAS operations in the **Specific** category must comply with the operational limitations set out in their authorization, or a standard scenario. In addition, UAS operations are classified in the **Certified** category where the competent authority, based on the risk assessment, considers that the risk of the operation cannot be adequately mitigated without the certification of the UAS and of the UAS operator and, where applicable, without licensing remote pilot [2019/947-SKYbrary, 2019].

In 2016, the Australian Civil Aviation Safety Authority (CASA) revised regulations concerning unmanned aircraft, incorporating new rules for remotely piloted aircraft. For the remote operation of UAVs weighing more than 2 kg, a pilot license and certificate are mandatory, covering various aspects like pilot information, maintenance, liability, and safety measures. Similarly, the German Air Traffic Act mandates authorization from the aviation authority for unmanned aerial vehicles weighing over 5 kilograms and not intended for recreational purposes. This authorization ensures privacy, public safety, and information protection. UAVs weighing more than 25 kilograms are restricted from flying beyond visual line of sight [Global Legal Research Center, 2021], [Singhal et al., 2018].

In France, two regulations have been recently implemented for civilian UAV use. These regulations classify UAVs into three categories: recreational, experimental, and particular activities UAVs. The rules cover UAV authorization, altitude limits, weight, and performance restrictions. Additionally, France's aviation laws prohibit UAV movement in specific geographic areas, such as military peripheries, historic monuments, national parks, and nature reserves. In India, the Director General of Civil Aviation (DGCA) under the Department of Civil Aviation formulates and regulates policies for remotely piloted aircraft. To fly UAVs, operators must obtain a Unique Identification Number and UAV Operator Permit, adhering to guidelines that prohibit access to restricted areas like Eco-Sensitive zones, areas beyond 500m into the sea from the coastline, and regions over 25 km from international borders [Global Legal Research Center, 2021].

Israel Civil Aviation Authority (CAAI) oversees laws related to manufacturing, training, and operations of UAVs, including flight elevation, regulated routes, and communication devices. These rules apply to all instructors, operators, and manufacturers. Violation of licensing rules incurs penalties similar to those applicable to manned aircraft. In the United States, the FAA has integrated unmanned aerial systems into the National Airspace System with a commitment to prioritize

safety, security, and capacity [Global Legal Research Center, 2021] [Singhal et al., 2018].

The Portuguese Civil Aviation Authority (Autoridade Nacional da Aviação Civil) (ANAC) oversees some regulations to ensure safe and responsible UAV operations. All UAV operators in Portugal must register their UAVs and follow the below rules. UAVs may fly no higher than 50 meters (170 feet) in the Open category and 120 meters (400 feet) in the Specific category. The ANAC may exempt specific category UAV operators. The operator must have a clear line of sight to the UAV at all times, and it should not fly farther than 500 meters away. It's best to avoid flying in airspace near residential or populated areas. Establish and maintain a one-kilometer safety buffer zone around all residential areas. A safety distance of 500 meters from isolated buildings, people, vehicles, animals, and structures is required unless the owner or person consents. Maintain a distance of at least eight kilometers from airports and three kilometers from heliports. UAVs are not permitted to be flown at night. Someone are not allowed to fly over, within, or near military installations, public utility installations, archaeological sites, or public or private facilities [TUCKER, 2023].

2.2 Healthcare Services

Healthcare services contain a wide range of medical, diagnostic, therapeutic, and support activities aiming at promoting, maintaining, and restoring health. These services are provided by a diverse group of healthcare professionals and organizations, including hospitals, clinics, physician practices, diagnostic laboratories, pharmacies, and home healthcare agencies. The delivery of healthcare services involves a complex system that is influenced by factors such as technological advancements, healthcare policies, financing mechanisms, and the evolving needs of the population. One of the crucial goals of healthcare services is to provide access to timely, safe, effective, and patient-centered care. This includes preventive services to promote wellness and early detection of diseases, diagnostic services to identify health conditions, therapeutic interventions to treat illnesses, and supportive services to assist individuals in managing their health and well-being. The provision of healthcare services is guided by medical knowledge, evidence-based practices, clinical guidelines, and ethical considerations. Healthcare professionals, such as physicians, nurses, pharmacists, and allied health practitioners collaborate to deliver comprehensive and coordinated care across different settings and specialties. Interdisciplinary teamwork and communication are essential for ensuring continuity of care and achieving optimal patient outcomes [WHO, 2020].

The healthcare industry is heavily influenced by policies and regulations at the local, national, and international levels. Governments play a critical role in regulating healthcare services, ensuring quality standards, licensing healthcare professionals, and promoting equitable access to care. Healthcare policies also address issues such as healthcare financing, insurance coverage, refund mechanisms, and healthcare delivery models. Healthcare services are supported by technological

advancements that have revolutionized diagnosis, treatment, and patient care. Electronic Health Records (EHRs), telemedicine, medical imaging technologies, robotic surgery, and personalized medicine are some examples of how technology has transformed healthcare delivery. These innovations have improved efficiency, accuracy, and accessibility, enabling remote consultations, real-time monitoring, and rapid dissemination of medical information [OECD, 2005], [Kumar et al., 2011].

2.3 Emergency Management System

According to the definition provided by the Federal Emergency Management Agency (FEMA) in United States, emergency management is the managerial function charged with creating the framework within which communities reduce vulnerability to hazards and cope with disasters. The vision of emergency management is to promote safer, less vulnerable communities with the capacity to cope with hazards and disasters. Emergency Management protects communities by coordinating and integrating all activities necessary to build, sustain, and improve the capability to mitigate against, prepare for, respond to, and recover from threatened or actual natural disasters, acts of terrorism, or other man-made disasters. Emergency management principles dictate that an emergency and disaster management plan must be comprehensive, progressive, risk-driven, integrated, collaborative, coordinated, clexible and professional [Bullock et al., 2017].

2.3.1 Emergency Management Phases

Emergency management is divided into four categories: **prevention and mitigation**, **preparedness**, **response**, and **recovery** [Zaki et al., 1997]. As shown in Figure 2.6, each phase is meant to feed the next phases in a circle. For instance, resources gathered in the event of an emergency during the second phase are used in the third and fourth phases. Similarly, information gathered in the recovery phase can be used to create more thorough prevention and mitigation strategies. Emergency management must function holistically to plan for an emergency from start to finish, as focusing only on one phase might lead to problems if unanticipated events happen. A skilled emergency manager knows the importance of creating a cohesive emergency management strategy with these four phases [Zaki et al., 1997] [Albtoush et al., 2011].

Prevention and Mitigation

The prevention and mitigation phase includes efforts to lower or eliminate the likelihood of a catastrophe and reduce people's and communities' susceptibility to the harmful effects of a disaster. This phase aims to lessen the cycle of catastrophic damage and have long-term sustainable impacts. The phase also aims to mitigate the consequences of a significant disaster by promoting long-term

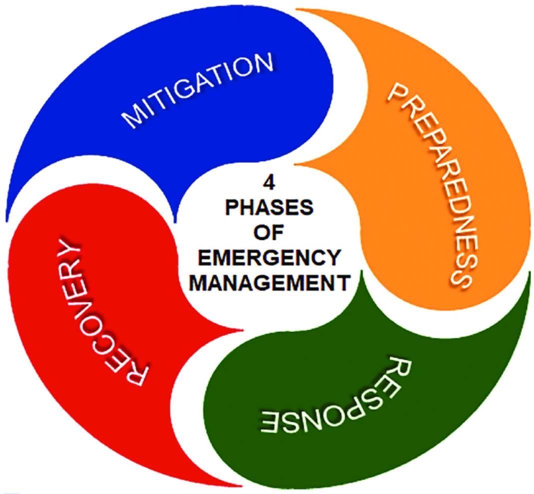

Figure 2.6: Four Phases of Emergency Management Phases [Albtoush et al., 2011]

initiatives to reduce the possible adverse effects of future disasters in impacted communities. Examples of prevention or mitigation include keeping objects off the floor to minimize contamination in the event of a flood or using earthquake straps to secure objects on shelves [Albtoush et al., 2011], [Wisner, 2004].

Preparedness

Preparedness is figuring out what people, training and tools are likely to be needed in different possible emergencies and developing plans in case a disaster happens, despite prevention and mitigation. Assessing the potential hazards and weak spots in a given environment, such as gathering food, water and medicine in anticipation of dangerous weather, is part of being ready. This ongoing process can involve all levels of government, the private sector and non-profit groups. Preparedness includes programs and systems established before an incident occurs, assisting and improving emergency or disaster response. Examples of readiness are stocking plastic sheeting and absorbent pads, placing them near areas where water contamination could be a concern, and putting water sensors in locations where leaks have occurred [Albtoush et al., 2011] [Cyganik, 2003].

Response

After a catastrophe, response operations will bring assistance, following plans made in the preparedness phase. The response phase focuses on immediate needs and limiting the possibility of subsequent harm caused by the emergency. Typically, the response phase addresses the immediate and short-term repercussions of a crisis within two to three days. Examples of response operations are shutting off contaminated water supply resources and placing objects affected by mold in antibacterial containers to prevent cross-contamination [Albtoush et al., 2011], [Tuscaloosa, 2003].

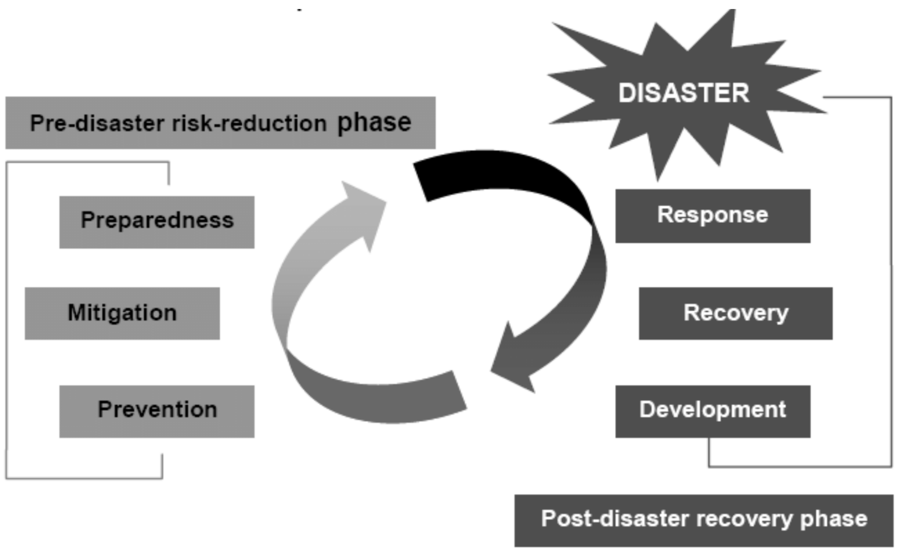

Figure 2.7: Traditional Emergency Model [Albtoush et al., 2011]

Recovery

Recovery efforts address a community's social, environmental, political, and economic components. These actions begin shortly after or simultaneously with the last parts of the response phase. Short-term recovery plans restore critical life-support systems to minimal operational requirements. Long-term recovery plans may last many years after a disaster and aim at getting things back to normal or even improving on the previous conditions while reducing the chance of a future emergency. After the recovery phase, emergency managers perform an emergency review. They analyze their plan's success and make changes to improve their methods. Part of an emergency manager's role is to understand what has not worked and improve each iteration of an emergency management plan to decrease the likelihood of damage or injury. One example of the recovery phase is removing damaged items or structures, potentially replacing them with versions that are less likely to be damaged in a future emergency [Albtoush et al., 2011], [Tuscaloosa, 2003].

2.3.2 Models of Emergency Management System

There are some kinds of models that respect the classical principles of the emergency management, such as Traditional model, Expand and Contract model, Kimberly's model, Tuscaloosa model, Circular model, and Manitoba integrated model [Albtoush et al., 2011]. The traditional model contains two phases: the pre-Disaster risk-reduction model phase and the post-disaster recovery phase. The first stage contains preparation, mitigation, and prevention. The second stage contains response, recovery, and development. It is a trivial model that does not consider the moment at which the crisis occurs. Moreover, data integration and decision-making are not easily achieved. The traditional model is shown in Figure 2.7.

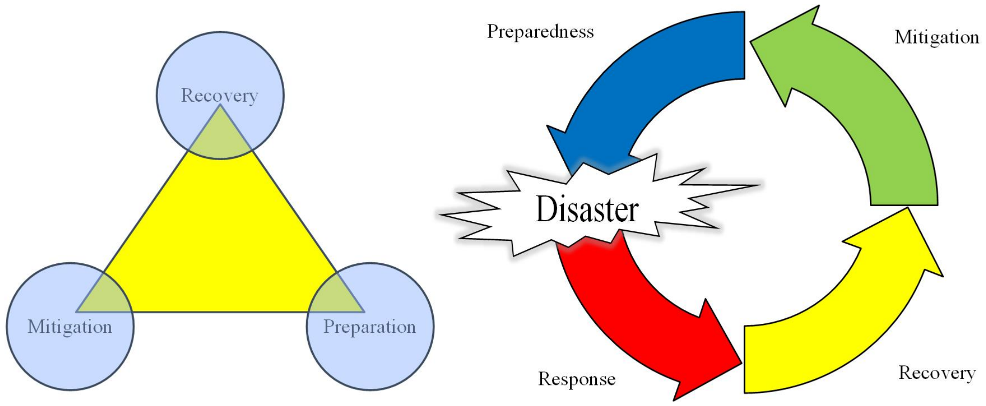

Figure 2.8: a) Kimberly Model, b) Tuscaloosa Model [Wisner, 2004]

In the Expand and Contract model [Albtoush et al., 2011], the activities and actions occur simultaneously and overcome the sequential nature limitations in the traditional model. This model does not consider external or internal factors related to the hazard event. Moreover, in the case of any hazard event, other strengthening factors could appear during the event that might have effects on the event, and this model does not take it into consideration. Unfortunately this model is not applicable for different cases of disaster. Also budget, cost, time, technology, infrastructure, supply chains are not taken into consideration by the authors of the proposal.

Kimberly model [Wisner, 2004] and Tuscaloosa model [Cyganik, 2003] decompose the disaster management cycle in four phases: mitigation, preparation, response and recovery. The main difference is that Kimberly model considered the mitigation and the response on the same base level, and the recovery on the top level (see Figure 2.8 (a)), while Tuscaloosa model (see Figure 2.8 (b)) limited the effect of disaster by inserting the mitigation at the beginning and the end of the cycle.

Both Kimberly and Tuscaloosa models require well trained employees in order to apply these phases effectively and can be utilized only in specific situations: emergency management in hospitals. Moreover; high budget will be expected for the employees.

Kelly decomposed the disaster management cycle into eight phases. He proposed a circular model that reduces the complexity of disasters and also handles the nonlinear nature of disaster events. The ability to learn from actual disasters is the main advantage of this model. The circular model is shown in Figure 2.9. This model requires developing a comprehensive database of disaster impact and input and output information, which requires well trained personnel to handle this information. Moreover, highly technological infrastructure is badly needed to achieve reasonable results [Albtoush et al., 2011].

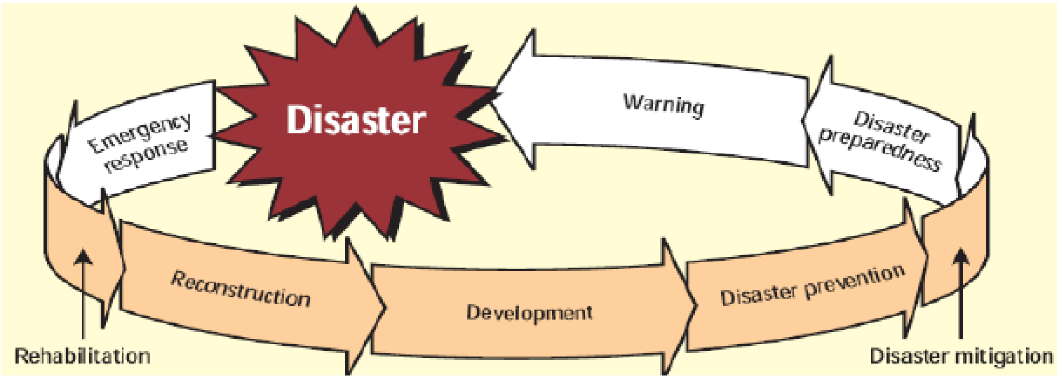

Figure 2.9: Kellys Circular Model [Albtoush et al., 2011]

2.4 Utilization of UAVs in Healthcare Services

UAVs in emergency services and healthcare has emerged as a engaged and transformative technology. UAVs offer a range of capabilities that can greatly enhance the effectiveness and efficiency of emergency response in medical use cases. These aerial vehicles are equipped with advanced sensors, cameras, and communication systems, enabling them to perform a variety of critical tasks in emergency situations and healthcare settings [Chauhan et al., 2019].

In the healthcare sector, UAVs have the potential to revolutionize patient care and medical logistics. UAVs can be used to transport medical supplies, including vaccines, blood samples, and organs for transplantation, in a timely and efficient manner [S.J et al., 2020]. Zipline, a UAV delivery company, partnered with the Rwandan government to deliver blood products to remote clinics, significantly reducing delivery times and saving lives [A, 2017]. In the United States, the nonprofit organization MissionGO conducted a successful pilot program in 2020, where they transported a human organ for transplant via UAV, demonstrating the potential for faster and more efficient organ transport [McNabb, 2021]. This is particularly beneficial in rural or remote areas with limited access to healthcare facilities. UAVs can also serve as a mobile telemedicine platform, allowing healthcare professionals to remotely assess patients in emergency situations or provide guidance during medical emergencies. By reducing transport times and improving access to healthcare services, UAVs have the potential to save lives and improve health outcomes [Watkins et al., 2020].

The utilization of UAVs in medical emergency services and healthcare is supported by several notable studies. For instance, a study published in the Journal of Medical Internet Research demonstrated the feasibility and accuracy of using UAVs for the delivery of Automated External Defibrillators (AEDs) to individuals experiencing cardiac arrest in real-world scenarios [S.J et al., 2020]. The World Health Organization (WHO) has also recognized the potential of UAVs in healthcare, launching the "Medical Drone Delivery Implementation Guide" to provide guidance on the implementation of drone delivery systems for medical supplies. UAVs offer immense potential in emergency services and healthcare by improving response times, enhancing situational awareness, and enabling efficient de-

livery of medical supplies. As technology continues to advance and regulations evolve, the integration of UAVs into these sectors is expected to become more widespread, ultimately contributing to saving lives and improving healthcare accessibility [Organization, 2020].

Recently, COVID has exerted a profound influence on healthcare operations at various levels, leading to a rapid expansion of health technology. Some changes were readily apparent, such as the surge in telemedicine and at-home lab tests, while others fulfilled urgent necessities. The growing need for safe solutions also drove the development of robotic support and the use of UAVs in hospitals. In a UNICEF guidance note, the organization identifies three basic types of potential use cases for UAVs: (1) delivery and transportation, (2) aerial disinfection, and (3) public space monitoring. During the pandemic, we have seen examples for all three cases and more. Let's see what the options are for UAVs in the future [Meskó, 2021]

2.4.1 Key Features of UAVs used in Healthcare

In mid-March 2017, Matternet, Swiss Post, and the Ticino EOC hospital group initiated a joint project, leveraging UAVs to autonomously transport laboratory samples between two hospitals in Lugano. The Federal Office for Civil Aviation (FOCA) granted approval for the project, and successful test flights using Matternet's cutting-edge M2 quadcopters were conducted in early 2017. Further testing is scheduled for summer 2017. Once the UAV meets all stringent criteria, independent UAV flights will become routine, expected to be fully operational by 2019 [Samples, 2017]. Matternet's M2 quadcopter boasts a capacity of up to two kilograms, a speed of 36 kilometers per hour, and a maximum range of 20 kilometers with a one-kilogram load on a single battery charge. Safety features include duplicate autopilots and essential sensors, with an automatic parachute deployment system in case of emergencies. The technology holds certifications from prominent aviation authorities worldwide, including the National Aeronautics and Space Administration (NASA) and FOCA [Krey and Seiler, 2019b].

Nevada-based UAV start-up Flirtey [D, 2017] achieved a significant milestone by executing the first Federal Aviation Administration (FAA)-sanctioned UAV delivery of medical supplies to a health clinic in rural Virginia, in collaboration with the University of Nevada at Reno. This successful delivery instills hope that UAVs can transport supplies efficiently, even in populated areas. Flirtey [D, 2017]has also demonstrated its UAV capabilities by transporting items in Nevada, Australia, and New Zealand. In May 2016, Ehang and Lung Biotechnology PBC joined forces for a fifteen-year collaboration aimed at optimizing the Ehang 184, the world's first autonomous human-transporting UAV, for organ deliveries. With thousands of people dying while awaiting organ transplants annually, this groundbreaking innovation in organ transport has the potential to save tens of thousands of lives [Enhang, 2017]. San Francisco-based UAV start-up Zipline and UPS have teamed up to create an autonomous UAV network in Rwanda, dedicated to delivering vaccines, blood, and medical supplies to clinics in remote regions. This project facilitates the delivery of essential items to 12 mil-

Table 2.2: key Feature of UAVsin Healthcare [Krey and Seiler, 2019b]

Drone	**Key Features**		
	Payload	Speed	Range
Matternet M2	2 kg	36 km/h	20 km
Flirtey	2.5 kg	24 km/h	
Ehang	100 kg	60 km/h	
Zipline	1.5 kg	10 0km/h	70 km
TU Delft ambulance	4 kg	100 km/h	12 km
Google UAVs	2.3 kg		
Vayu UAVs	2 kg		60 km

Table 2.3: Application of UAVs in Healthcare [Krey and Seiler, 2019b]

Drone	**Application**	**Country**
Matternet M2	Laboratory Sample Delivery	Switzerland Guinea Haiti
Ehang	Organ Delivery	New Zealand Nevada Australia
Ehang	Organ Delivery	UAE Emirates
Zipline	Vaccine and Blood Delivery	Rwanda
TU Delft ambulance	AED Delivery	Netherland
Google UAVs	Medical Supply Delivery & Instruction	only patent
Vayu UAVs	Blood Delivery	Madagascart

lion people within 30 minutes. Zipline and UPS are committed partners, seeking to implement this concept in other countries as well [A, 2017]. These UAVs can carry payloads of up to 3 pounds and reach speeds of 100 km per hour, delivering cargo via paper parachutes without landing on missions. Table 2.2 outlines the examples of UAVs currently used in healthcare [Krey and Seiler, 2019b].

The University of Delft in the Netherlands developed a pioneering ambulance UAV equipped with a defibrillator and integrated video capability. In emergency situations, the UAV swiftly reaches the spot, providing instructions to individuals near the patient until emergency personnel arrive. Unlike traditional services, which take 10 minutes to cover 4.6 square miles, this technology can traverse the same distance in just one minute, showing immense potential to elevate cardiac arrest patients' survival rates from 8% to 80%. Google also embraces a similar approach, obtaining a patent for a medical supply UAV to aid individuals in need, reaching patients before emergency services. Moreover, in Madagascar, Vayu UAVs efficiently transported blood samples for testing to a central laboratory. Table 2.3 provides a comprehensive summary of the various fields in healthcare where UAVs are currently employed [Dragoela, 2016], [Andrew, 2016].

2.4.2 Medical Drone Market

According to the analysis conducted by Data Bridge Market Research, the global medical UAVs market is projected to experience substantial growth with a Compound Annual Growth Rate (CAGR) of approximately 16.86% during the forecast period from 2022 to 2029. The market value, which stood at USD 227.53 million in 2021, is expected to reach USD 791.34 million by 2029. The comprehensive market report by Data Bridge Market Research provides valuable insights, including market value, growth rate, segmentation, geographical coverage, key market players, and the overall market scenario. Additionally, the report encompasses in-depth expert analysis, patient epidemiology, pipeline analysis, pricing analysis, and regulatory framework to offer a holistic view of the market landscape [ReAnIn, 2023].

Despite wide potential applications in healthcare, the use of UAVs in practice has been fairly limited [Cohen and Shaheen, 2021]. Safety and security concerns have led to tight regulations on airspace. This makes it difficult to phase in UAVs for practical (rather than recreational) use. UAVs have a bad reputation due to their potential abuse in breaching privacy, violating human rights and irresponsible use by hobbyists, particularly at airports. Consequently, only a small proportion of the potentially vast benefits offered by UAVs in healthcare have been realised [Enhang, 2017].

Figure 2.10 illustrates an overview of medical drone segmentation beaded on type, payload, region, end user and application in industry research [S N, 2023]. The categorization of medical UAVs based on their type is a fundamental aspect of segmentation. It distinguishes between various UAV configurations, such as fixed-wing UAVs, multirotor UAVs (including quadcopters, hexacopters, and octocopters), and hybrid UAVs. These different UAV types offer distinct advantages and limitations, influencing their suitability for specific medical tasks. Another crucial factor for segmentation is payload capacity. It divides into categories: under 2 kg, between 2 to 4 kg, and over 4 kg. Furthermore, this segmentation encompasses various geographic regions, including North America, Latin America, Europe, East Asia, South Asia, and Oceania. It also extends to a wide range of end-user sectors, comprising hospitals, clinics, emergency services, research institutions, government agencies, and commercial service providers. Additionally, the segmentation covers diverse application domains, such as vaccine delivery, inspection and maintenance, surveillance and monitoring, transplant transport, emergency response, and various other applications [S N, 2023].

The coronavirus crisis has acted as a catalyst for the adoption and acceptance of UAVs in healthcare. There are two main reasons for this: first, The need to deliver medical care/supplies quickly is more urgent and second, Social distancing and quarantine measures have made remotely operated systems particularly valuable As a result of coronavirus, how has UAV use changed or adoption accelerated. Some examples included below [Stewart, 2020]:

- **AVY WINGS UAVs in Healthcare:** Dutch company Avy manufactures wing UAVs for use in urban healthcare logistics, rural delivery of supplies, and

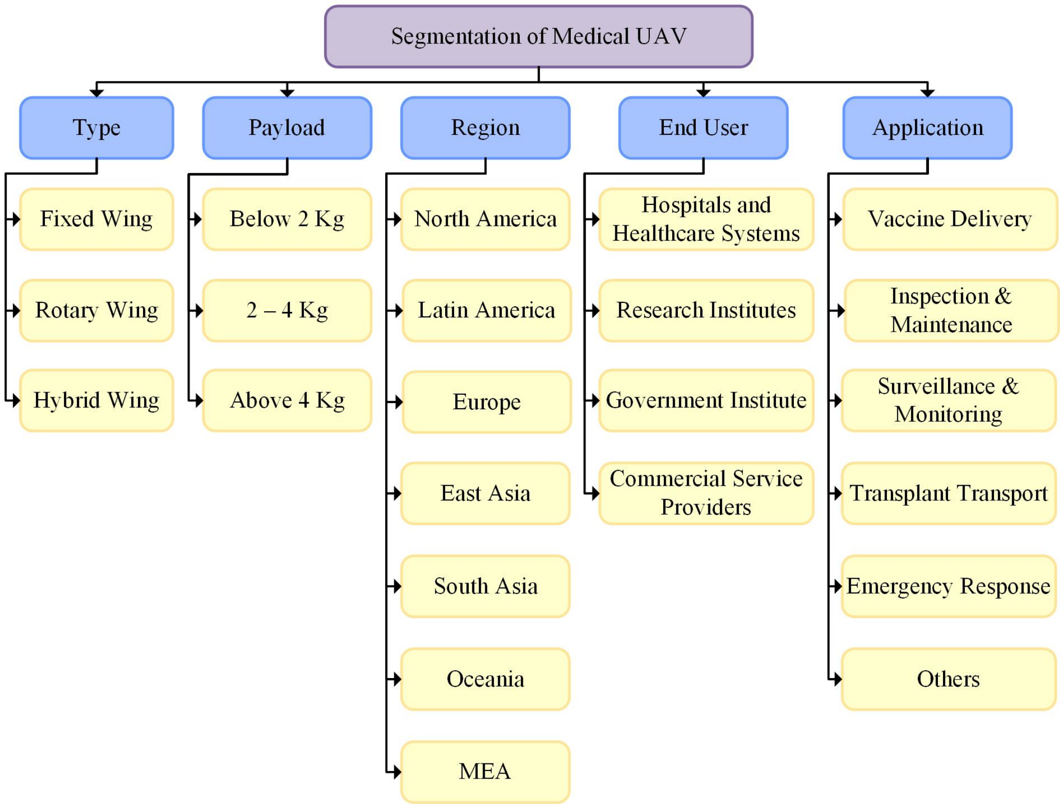

Figure 2.10: Segmentation of Medical Drone Industry Research [S N, 2023]

first response emergency services. Avy responded to the pandemic by exploring the use of wing UAVs to transport COVID-19 samples from small municipalities to labs in larger cities. This would help contain the virus and minimise risk of the virus spreading.

- **IRISH Drone Startup Switches From food to Medicine:** The Irish start-up launched their drone delivery service earlier this year, with the aim of moving road-based food delivery into the skies. Manna Aero's trial delivery of takeaways to college students in mid-March had to be halted due to the coronavirus lockdown, but this did not deter them from switching focus to help in the crisis. The company has instead been working with the Irish Health Service Executive to deliver medicines and other essential supplies such as break and milk to vulnerable people in the rural town of Moneygall. Local GPS write prescriptions after a video consultation, which the UAVs deliver directly to homes. This represents a first in Ireland. Manna Aero is equipped to handle up to 100 deliveries a day, and hopes to bring trials to the UK soon.

- **Medical Supplies to the ISLE of wight:** The UK's lockdown in 2020 triggered the government to grant permission for a UAV to deliver medical supplies across the Solent to a hospital on the Isle of Wight. This is part of a UK government project to develop a system allowing manned and unmanned aircraft to operate in the same airspace. The UAV, developed by the University of Southampton and funded by the start-up Windracers, was given permission to fly as part of the British government's Covid-19 response. It

has a range of 1,000km and can carry up to 100kg. Compared to the more traditional ferry, this novel approach allows faster, more frequent, and more reliable delivery of medical supplies.

- **NHS Drone Delivery in Scotland:** The Covid-19 response has triggered a partnership between the UAV delivery provider Skyports and Thales to trial the delivery of medical supplies. The two-week pilot is backed by NHS Highland, and Argyll and Bute Council, with UAVs supplied by unmanned aircraft-maker Wingcopter. The delivery service will be based in Oban. It aims to ensure that isolated communities on the Isle of Mull (16km away) have access to COVID-19 tests and sufficient personal protective equipment (PPE). This trial is a crucial milestone for unmanned aviation in the UK. It was granted as an exception to current rules by the Civil Aviation Authority.

- **Drone Used for Covid-19 Response In Africa:** Zipline is a US UAV company that delivers supplies to rural communities in Rwanda and Ghana. In order to support the Covid-19 response in Africa, Zipline changed its focus to using UAVs to provide clinics with PPE and coronavirus test samples. The lightweight UAVs deliver to clinics up to 85km away. There are plans to use the UAVs to deliver supplies directly to the elderly and vulnerable who need to self-isolate. Zipline CEO Keller Rinaudo thinks that UAV deliveries could play a vital role both during the current crisis and in the coming months and years.

2.5 Technology Acceptance

In the modern era, technology plays a vital role in shaping various aspects of our lives, ranging from personal to professional domains. However, the successful implementation of technology relies heavily on its acceptance by end-users. Understanding and predicting technology acceptance is crucial for ensuring the integration and adoption of innovative solutions.

The Technology Acceptance Model (TAM) is one of the most widely recognized theoretical frameworks for understanding technology acceptance [Davis, 1989]. Introduced by Davis in 1989, TAM brings up that perceived **usefulness** and **perceived ease of use** are the two primary determinants of users' intention to adopt a technology. Perceived usefulness refers to the user's belief that a particular technology will enhance their performance, while perceived ease of use relates to the perceived simplicity and ease of learning to use the technology [Davis, 1989].

As depicted in Figure 2.11, the TAM claims that an individual's intention to use a system is influenced by their perception of its usefulness and ease of use. This intention to use, in turn, acts as a mediator for actual system utilization. Notably, perceived usefulness is directly affected by the perception of ease of use. The connections between these two pivotal constructs and users' attitudes, intentions, and the actual adoption of the technology are turned on based on the theoretical framework of the Theory of Reasoned Action (TRA) [Montano and Kasprzyk, 2015] Within this framework, attitude and perceived usefulness collaboratively

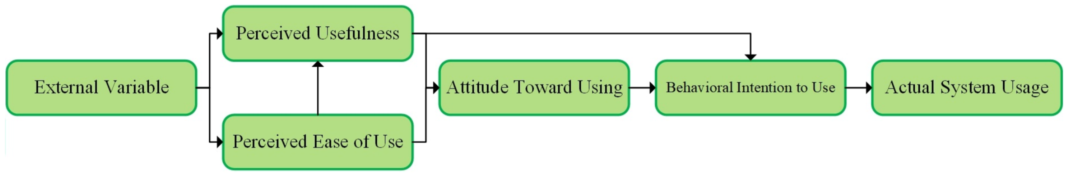

Figure 2.11: Technology Acceptance Model [Davis, 1989]

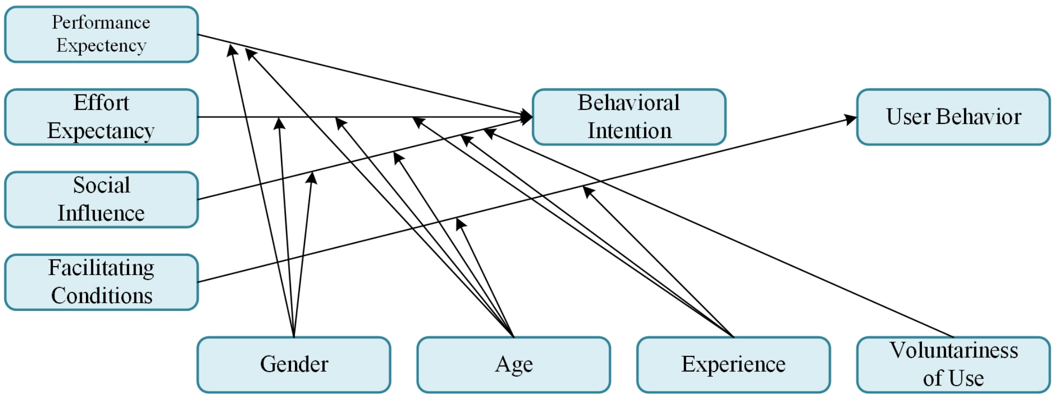

Figure 2.12: The Unified Theory of Acceptance and Use of Technology (UTAUT) Model [Venkatesh et al., 2003a]

shape behavioral intention, while attitude itself is determined by the perceived factors of usefulness and ease of use [Samaradiwakara and Gunawardena, 2014].

Building upon TAM, [Venkatesh et al., 2003a] proposed the Unified Theory of Acceptance and Use of Technology (UTAUT), which incorporates additional factors influencing technology adoption. As shown in Figure 2.12, UTAUT includes performance expectancy, effort expectancy, social influence, and facilitating conditions as determinants, along with the moderating effects of gender, age, and experience. This model is well-known for studying how people use information systems and what difficulties they face. Venkatesh's research team [Venkatesh et al., 2003b] created it using eight important ideas from the past. They tested this model with real data from users in four organizations. In this model, they found that four things really matter: how well something works, how easy it is to use, what other people think, and whether it's convenient. They also looked at four other things: gender, age, experience, and whether people have to use it. When they tested it in two other organizations, it explained 70% of why people want to use technology, which is much better than the original eight ideas. They found that how well something works is the most important for most people, especially men and young people. How easy it is to use also matters, especially for women and older people, but it matters less as people get more experience. What other people think also matters, but it depends on all four other things. [Venkatesh et al., 2003b].

2.5.1 UAVs Acceptance Model

UAVs presenting innovative solutions for efficient and rapid healthcare delivery. The acceptance and integration of UAV technology in healthcare settings are critical for its successful implementation and widespread adoption. To understand the factors influencing the acceptance of UAV technology in healthcare, researchers have proposed the UAV Technology Acceptance Model [Venkatesh et al., 2003a]. For instance, uses the TAM to understand the factors that affect the adoption of UAV delivery systems by logistics service providers for humanitarian operations [Edwards et al., 2023].

The UAV Technology Acceptance Model is a conceptual framework designed to examine the determinants that influence healthcare professionals' and stakeholders' intention to adopt and use UAVs in various healthcare applications. Similar to the original Technology Acceptance Model, the UAV Technology Acceptance Model focuses on two primary factors: perceived usefulness and perceived ease of use [Venkatesh et al., 2003a]. Perceived usefulness in the context of UAVs in healthcare refers to healthcare professionals' beliefs about the benefits and advantages of utilizing UAV technology in medical practices. These benefits might include faster response times during emergencies, enhanced access to remote and inaccessible areas, and improved delivery of medical supplies, such as medications and diagnostic equipment. Perceived ease of use involves the extent to which healthcare professionals perceive UAV technology as user-friendly and easy to operate in a healthcare setting. A user-friendly UAV system with intuitive controls and automated functionalities can positively impact its acceptance and adoption by healthcare providers [Daud, 2016].

2.5.2 Technology Acceptance in Healthcare

The healthcare industry is continuously evolving, with technology playing an increasingly prominent role in enhancing patient care, improving operational efficiency, and driving medical advancements. However, the successful adoption and implementation of technology in healthcare heavily rely on understanding and addressing the barriers to technology acceptance. This section presents a comprehensive exploration of Technology Acceptance in Healthcare, focusing on key factors and models that influence the acceptance of innovative healthcare technologies. According to [Calvin et al., 2011], there are four essential factors that impact technology acceptance in healthcare:

- **Perceived Relevance and Benefits**: Healthcare professionals and patients are more likely to embrace technology when they perceive it as relevant to their needs and believe that it will bring tangible benefits to patient outcomes, diagnosis accuracy, and treatment effectiveness. Demonstrating how the technology can improve patient care and optimize healthcare workflows will contribute to higher levels of acceptance.

- **Usability and Ease of Use**: The usability and ease of use of healthcare technologies are critical factors in their acceptance by healthcare professionals.

user interfaces, simplified workflows, and minimal disruption to existing processes are essential to ensuring a successful integration of technology into healthcare settings.

- **Trust and Security**: Ensuring the privacy and security of patient data is paramount in healthcare technology adoption. Stakeholders must build and maintain trust by implementing robust data protection measures, complying with relevant regulations, and addressing concerns related to data breaches and misuse.

- **Training and Support**: Comprehensive training and ongoing support for healthcare professionals are crucial to building confidence in using new technologies. enough training ensures that healthcare professionals are proficient in utilizing technology effectively, thus reducing resistance to change and facilitating technology acceptance.

  Technology acceptance in healthcare is vital for driving positive patient outcomes, enhancing healthcare processes, and fostering continuous medical advancements. By recognizing and addressing the factors that influence technology acceptance, healthcare organizations can promote a culture of innovation and integration of technology in healthcare settings. use of established models like the TAM and the UTAUT provides a robust framework for understanding user attitudes and behaviors, ultimately leading to successful healthcare technology implementations. Through collaborative efforts and a focus on user-centric design, the healthcare industry can embrace technological advancements to deliver higher quality care and improve overall patient experiences [AlQudah et al., 2021].

2.6 Summary

The background section contain some essential elements such as UAV,emergency management services and healthcare systems. UAV, are innovative aerial platforms equipped with advanced sensors and cameras, offering transformative capabilities for a range of industries. In the context of emergency management and healthcare, UAVs have emerged as valuable tools, facilitating search and rescue operations, delivering medical supplies, and providing telemedicine support. Emergency management services involve the coordination and response to various disasters and crises, ensuring the safety and well-being of affected communities. Healthcare systems encompass the infrastructure, resources, and services that provide medical care to individuals. The combination of these elements highlights the potential for UAVs to revolutionize emergency services and enhance healthcare delivery, ultimately improving outcomes for individuals and communities in need.

Chapter 3

State Of The Art

The utilization of UAVs in the domains of emergency management and healthcare has witnessed a transformative evolution in recent years. These versatile aerial platforms have emerged as a tool to enhance emergency response, optimize resource allocation, and reinforce healthcare delivery. In this literature review section, we explore the growing body of research and empirical evidence that underscores the vital role of UAVs in these critical sectors. By combining insights from various sources, we aim to provide a comprehensive understanding of how UAVs are reshaping emergency management strategies and revolutionizing healthcare practices, ultimately contributing to more efficient, effective, and responsive systems in the face of challenges and crises.

3.1 Methodology

In this section, I describe the methodology used to perform this literature review on using UAVs for emergency services and healthcare in urban airspaces, which is based on well-established guidelines for conducting systematic literature reviews (SLR) [Kitchenham, 2004] and contains following steps:

- **Definition of research questions:** The initial step involved the definition of a series of research questions that served as the primary objectives of our study.
- **Inclusion and exclusion criteria:** In this step, we established the criteria for inclusion and exclusion as well as the quality assessment criteria, which will be applied to the primary studies gathered in the previous step. The aim is to select and include relevant works in our systematic review that align closely with the research objectives and scope of our study.
- **Identifications of studies:** We then selected and determined the primary databases, such as search engines and online libraries, commonly utilized by researchers to locate reliable and peer-reviewed studies that contribute to the specific subject of interest, using drones in emergency management services and healthcare. Subsequently, we established a general query string

to conduct the search, and we employed the snowballing process to supplement the identification of relevant studies.

- **Analysis of related surveys:** In this phase, we identified various review studies, such as surveys, systematic reviews, and mapping studies, that somehow cover the subject of using UAVs for emergency service management and healthcare services. Our objective was to find the gaps and limitations present in the existing review studies.

- **Data extraction and synthesis of related papers:** After analyzing the related surveys, we expanded our analysis by considering additional research papers and articles based on defined research questions and criteria. We extracted relevant data from the selected primary studies based on our research questions. This extracted data is then synthesized to enable us to address and answer the research questions effectively.

The following sections present each of the above steps in further detail.

3.2 Research Questions

We formulated the following research questions, which serve as the foundation for the objectives of this systematic review:

1. Which specific applications are the primary focus within the domain of healthcare service?

2. Which specific applications are the primary focus within the domain of emergency management?

3. What are the primary challenges associated with utilizing UAVs for emergency services and healthcare in urban airspace?

3.3 Inclusion and Exclusion Criteria

The present review seeks to explore the use of UAVs within the domain of healthcare services, emergency management, and disaster management in both urban and remote areas. While the primary emphasis of this thesis lies in healthcare services and medical emergency management in urban airspace, exploring research across the aforementioned domains can significantly enhance our comprehension of the ongoing efforts related to UAV utilization in the related domains. Furthermore, it helps in the identification of the existing gaps and limitations within these areas.

To refine the identified studies, we applied a set of inclusion and exclusion criteria. The inclusion criteria for the selection of studies encompass a range of factors aimed at providing a comprehensive understanding of the subject matter. Studies

written in English form the primary language criterion to ensure accessibility and understanding. Furthermore, the studies must focus on the utilization of UAVs in emergency management, disaster management, and healthcare services, with a specific emphasis on applications like search and rescue, medical care, and medical delivery. The review also encompasses investigations into the integration of UAVs into existing emergency response and healthcare delivery systems, both in urban and remote contexts. The impact of urban environments on UAV design and operation, economic considerations, ethical and legal implications, technical requirements, operational characteristics, safety, and regulatory concerns constitute key areas of interest in the review. This thorough inclusion criterion ensures a comprehensive examination of the multifaceted role of UAVs in emergency and healthcare settings.

Conversely, the exclusion criteria serve to refine the scope of the review by excluding studies that do not align with the specific research question and objectives. Studies that focus on UAVs for non-emergency purposes, such as commercial or recreational use, are excluded due to their divergence from the review's central themes. Moreover, studies not published in English or lacking peer-reviewed status are excluded to maintain the quality and validity of the sources. While the review emphasizes contemporary insights, studies older than a specific date are not automatically excluded if they provide pertinent and up-to-date information. Additionally, studies that do not directly contribute to the research question or lack clear methodology and sufficient results are excluded to maintain the rigor and relevance of the review's findings. By adhering to these exclusion criteria, the review ensures a focused and insightful exploration of the integration of UAVs in emergency and healthcare applications within urban areas.

3.4 Identifications of Studies

This literature review aims to analyze a range of articles centered on the utilization of UAVs in healthcare and emergency management services. The search was conducted in electronic databases such as Google Scholar, PubMed, Scopus, and Web of Science. The search using the specified keywords yielded a total of 693 papers. Subsequently, these papers were meticulously examined by considering their titles, abstracts, and content. Through this comprehensive analysis, we identified a total of 16 review papers that are directly related to the use of UAVs in emergency services and healthcare.

Then, we broaden our investigation by looking at more research papers and articles that match our specific research question and criteria. The query resulted in a total of 170 papers, which underwent a thorough evaluation.

3.5 Analysis of Related Surveys

This review looks at some review papers and many articles about how drones are used in healthcare and emergency services. In the following section, we present a thorough analysis of these relevant studies, which are listed in Table 3.1.

Table 3.1: List of the Analyzed Review Papers

Reference	Year	Articles	Duration	App domain	EMS Phases	Purpose
Stephan et al.	2022	4	2016-2021	Healthcare	-	Delivery of Medicine, Medical Device
Lim et al.	2022	26	2016-2021	Healthcare	Response	AED Delivery
Zailani et al.	2020	11	2009-2019	Healthcare	-	Medical Product in maternity
Robakowska et al.	2022	104	2017-2021	Healthcare	Response	Medical Emergency Delivery
Wang et al.	2019	47	2012-2020	Emergency Management	Response	aid supply delivery and surveillance
Zailani et al.	2021	28	2017-2020	Healthcare	-	Medical Product in maternity
Bhatt et al.	2018	6	2007-2018	Healthcare	-	Blood, AED, Medication Delivery
Sanz-Martos et al.	2022	6	2013-2021	Emergency Management	Response	Monitoring and aid supply delivery
Daud et al.	2022	52	2009-2021	Emergency Management	Response	Monitoring, Mapping, Medical product delivery
Roberts et al.	2022	38	2010-2021	Emergency Management	Response	AED Delivery
Kucharczyk and Hugenholtz	2021	18	2006-2021	Emergency Management	All	Mapping, Medical product delivery
Hiebert et al.	2020	29	2007-2019	Healthcare	-	medicine delivery
Rosser Jr et al.	2018	202	2014-2017	Emergency Management	Response	Telemedicine, Medical delivery
Kerle et al.	2019	26	2005-2019	Emergency Management	Response & Recovery	Mapping and aid supply delivery
Carrillo-Larco et al.	2018	5	2008-2018	Emergency Management	-	AED Delivery

Stephan et al. [Stephan et al., 2022], provides insights into the potential of drones in healthcare delivery. The authors discussed the usability, acceptance, and effectiveness of drones in medical delivery processes, as well as the health-related outcomes and user experience of human-drone interaction.The authors conducted a scoping review to investigate the current state of the literature on human-drone interaction in healthcare, with a focus on the delivery of medical supplies. The study does not focus on any specific phase of emergency management. The authors concluded that drones have the potential to improve the delivery of medical supplies, especially in rural and remote areas, and can reduce the time and cost of transportation. However, they noted that there are still challenges such as regulatory issues, safety concerns, and public acceptance.

Lim et al. [Lim et al., 2022], conducted a scoping review on the use of drones in out-of-hospital cardiac arrest situations. The study focused on the potential use of drones as a means of delivering AEDs to the scene of a cardiac arrest in order to improve response time and increase the chances of survival for the patient. The study primarily focuses on the response phase of emergency management, which involves the provision of emergency medical services to individuals who require urgent medical attention outside of a hospital setting. This study con-

cluded that while there is growing interest in using drones to deliver AEDs in emergency medical services, careful evaluation and addressing of real-world delays, challenges, and barriers to drone use in AEDs delivery is required for these time savings to translate to reduced times to defibrillation and improvement in out-of-hospital cardiac arrest outcomes. The authors concluded that drones can deliver an AEDs faster than the current emergency management services in a controlled environment, thereby decreasing time to defibrillation and improving out-of-hospital cardiac arrest outcomes. However, due to the limited number of studies performed and the heterogeneous nature of the studies in their methodologies, simulation models, and outcomes, a scoping rather than systematic review was conducted. Hence, risk of bias and quality assessments of the included studies were not performed, and the authors were unable to draw comparisons across studies. Furthermore, there are limited data from real-world implementation of drone networks, which is imperative in obtaining an understanding and drawing real conclusions regarding the multiple factors that influence the effectiveness of this solution.

Zailani et al. [Zailani et al., 2020], conducted a systematic review to identify the potential of drones to deliver medical supplies in limited conditions and during obstetric emergencies in maternal healthcare. This study focuses on the response phase of emergency management in maternal healthcare. The authors found that the use of drones for medical product transportation in maternal healthcare has great potential and could overcome the limitations of current modes of transportation. However, further research is needed to fully understand the feasibility, safety, and cost-effectiveness of using drones in this context. Additionally, most studies were still in the simulation or experimental stages, with a large window for future research needs in real-life situations in obstetric emergencies. Finally, while reviews on Medical products Ground Transportation (MedGRT) and Medical products Aerial Transportation (MedART) are increasing in numbers, most of the previous studies were done separately, either focusing on the efficiency of MedGRT or MedART without comparing one to the other.

Robakowska et al. [Robakowska et al., 2022b] studied the feasibility of using drones in emergency medical systems and analyzed the applicability of UAVs to support emergency medical systems. This study focuses on the response phase of emergency management, specifically the use of UAVs in transport and emergency urgent care. The study found that i) UAV can reduce AED waiting times in metropolitan cities, but bad weather can limit their effectiveness; ii) The use of UAVs in logistics distribution, especially in complex terrain, both urban and remote from human concentrations, can be used together with a ground vehicle; iii) GIS analyses can identify areas of out-of-hospital cardiac arrests (OHCAs) and serve as tool to quantify the need for AED-equipped drones. Also, this study presented that the most significant limitation of UAVs is the battery/fuel issue, which can limit their range and endurance. UAVs often waste a lot of time and fuel to take off and reach difficult places, places covered by warfare, complex terrains including cities, etc. Considering infrastructure problems in terms of emergencies, UAVs can be used to support transportation communications by acting as a communication relay.

Wang et al. [Wang et al., 2021] conducted a scoping literature review on the use of drones in the humanitarian sector, with a particular focus on the ethical considerations associated with this emerging technology. This review identified 11 key areas of concern associated with humanitarian drones, including minimizing harm, maximizing welfare, substantive justice, procedural justice, respect for individuals, respect for communities, regulatory gaps, regulatory dysfunction, perceptions of humanitarian aid and organizations, relations between humanitarian organizations and industry, and the identity of humanitarian aid providers and organizations. the study acknowledged some limitations, including the challenge of creating boundary definitions for the concept of "humanitarian use" and operationalizing this concept in the search and selection process.

Zailani et al. [Zailani et al., 2021b] aimed to assess and report the possible application of drone technology in improving the current situation in maternal healthcare in Malaysia, the way it can be adopted, the possible key challenges with its implementation, and finally provide recommendations for practitioners, policymakers, commercial sectors, investors and researchers studying this rising phenomenon of drone technology. The main finding of this study is that the use of drone technology has the potential to improve access to maternal healthcare in remote areas of Malaysia, where traditional transportation methods may be limited or unavailable. However, implementing drone technology in this context also poses several challenges, such as regulatory issues, technical limitations, and public acceptance.

Bhatt et al.[Bhatt et al., 2018], grouped UAV applications in medicine into three categories: prehospital emergency care, expediting laboratory diagnostic testing, and surveillance. The main application domain of the study is the use of UAVs in telemedicine. They also discuss the challenges and limitations of using UAVs in telemedicine and suggest ways to address them. This study focuses on the prehospital phase of emergency management. The authors also noted that several ethical, technical, and clinical questions need to be addressed before drones can be used on a large scale. They recommended that the safety and effectiveness of this technology need to be thoroughly discussed and that the limitations of UAVs in telemedicine need to be addressed before widespread implementation.

Sanz-Martos et al. [Sanz-Martos et al., 2022] conducted a systematic review to identify the main applications, benefits, and limitations of using drones in emergency and urgent health care response. This study explained the available evidence on the use of drones in emergency health care compared to traditional health care. It also highlighted how drones can improve the distance traveled to locate accident victims, perform triage prior to the arrival of the health care units, and improve the time and quality of the care provided. The main findings of this study are that drones covered a significantly larger area than other traditional tracking methods and were very useful for performing preliminary triage, determining needs, and knowing the scene prior to the arrival of rescuers. In addition, drones reduced the time required to locate the victim. The study highlighted the potential benefits of using drones in health emergencies, such as avoiding endangering rescuers and reducing the time required to locate victims. The review also noted some limitations and challenges associated with using drones in health

emergencies, such as the need for proper training and the potential for technical difficulties.

Daud et al. [Daud et al., 2022], conducted a scoping review of the use of drones in humanitarian aid and disaster response. They aimed to identify the current state of knowledge on the use of UAVs in disaster management, including their applications, benefits, limitations, and future directions for research and practice. The study identified four potential applications of drones in disaster response: mapping or disaster management, search and rescue, transportation, and training. However, the evidence of their use in mass disasters is still unclear and scarce. This study identified several limitations and challenges to using drones in disaster management. These included the overestimation of drone performance in simulations compared to real-world disasters, the lack of evidence for disaster victim identification, the absence of standardized drone procedures and regulations, and the presence of prohibited areas where drones cannot be deployed. The study recommended addressing these challenges through additional research, enhanced regulation of drone deployment, and the development of appropriate drone properties for disaster response.

Roberts et al. [Roberts et al., 2023a] aimed to review the current evidence on the use of drones for delivering time-critical medical supplies in emergency medical services such as automated external defibrillators, naloxone, and anti-epileptics, in out-of-hospital emergencies. They concluded that drones can significantly improve patient outcomes in time-sensitive emergencies, such as cardiac arrests, strokes, myocardial infarctions, drug overdoses, seizures, and trauma. This study focused on the response phase of emergency management and highlights the potential benefits of using drones in Emergency Medical service (EMS), particularly in delivering time-critical medical supplies in out-of-hospital emergencies. Also, it identified several barriers and knowledge gaps that need to be addressed before drones can reach their full potential in EMS. These included regulatory and legal issues, technical challenges, safety concerns, public acceptance, and integration with existing EMS. Further research is needed to demonstrate the functionality of drones in real-world scenarios and to integrate drones into the existing EMS structure.

Kucharczyk and Hugenholtzl [Kucharczyk and Hugenholtz, 2021], provided a comprehensive analysis of global trends, biases, and research opportunities in drone-based remote sensing for disaster management. The main application domain of this study is drone-based remote sensing for supporting disaster mitigation, preparedness, response, and recovery of floods, cyclones and other windstorms, earthquakes, landslides and other mass movements, wildfires, and volcanic eruptions. The authors identified the most commonly demonstrated activities and functions in each phase of emergency management and provided recommendations for future research. Most studies have focused on rural areas and observed features from the natural environment, while there is a need for more studies demonstrating the use of drone-based pre- and post-disaster remote sensing of the built environment in urban areas. There is a need for more studies in low, lower-middle, and upper-middle income countries and territories, as lower-income areas are disproportionately affected by disasters. The authors identified

the most commonly demonstrated activities and functions of drones in disaster management, as well as the most commonly used drone hardware and remote sensing data utilization.

Hiebert et al. [Hiebert et al., 2020] studied the current state of research on the use of drones for healthcare or health-related applications in North America. The main application domain of this study is the use of drones for healthcare or health-related purposes in North America, which includes environmental monitoring, emergency service delivery, search and rescue operations, and remote medical support, among others. The study focused on population segments in the medical community and paid limited attention to how patients and communities interacted with and perceived the use of drones for health-related applications. The primary focus of the sample was on how drones transported medical equipment, medications, and biological samples, and the authors highlighted how drones may enable healthcare providers to reach individuals in difficult-to-reach locations. The researchers identified several areas for future research to improve the use of drones for healthcare and health-related purposes, such as improving specific elements of drone technology, testing the viability of biological samples transported by drones, enhancing information privacy, and increasing understanding of human-technology interactions.

Rosser Jr et al. [Rosser Jr et al., 2018a] conducted a comprehensive review of current and future drone applications in medicine. The study focuses on the use of drones in various phases of emergency management, including public health and medical surveillance, disaster relief, and medical transport systems. The findings of this study suggest that drones have the potential to be used in a wide range of medical applications, from delivering medical supplies to remote areas to assisting in surgical procedures in simulated harsh environments. The authors of this study found that there has been a slower expansion in the field of medicine in terms of drone applications, despite the fact that drones have the ability to gather real-time data cost-effectively and deliver payloads.

Kerle et al. [Kerle et al., 2019], reviewed the latest developments in using UAVs for detecting and characterizing structural damage in disaster response and emergency management as well as the various sensors and techniques that can be used to collect and process data. They also provided examples of recent studies that have used UAVs for structural damage mapping and discussed the potential applications and future directions of this technology. The study focuses on the damage assessment phase of emergency management, which is critical for identifying the extent and severity of daUAV-based structural damage mapping, including the various sensors and techniques that can be used for data collection and processing. The author also evaluated the actual usability and practical value of emerging methods for operational damage mapping, including local mapping by first responders. Overall, the review concluded that UAV-based damage mapping has great potential for improving disaster response and recovery efforts.

Carrillo-Larco et al. [Carrillo-Larco et al., 2018] conducted a systematic review to identify the potential benefits and limitations of UAVs for health-related purposes, particularly in emergency situations. The study focused on the response phase of emergency management, which involves the mobilization of resources

to address the emergency situation, and found that they have the potential to improve access to healthcare, particularly in remote or hard-to-reach areas. The findings of this study suggest that drones have the potential to improve health outcomes in emergency situations by providing faster and more efficient delivery of medical supplies, equipment, and personnel. The review also identified several limitations to the use of drones in healthcare, including regulatory and logistical challenges, as well as concerns around privacy and security. Based on the findings of the review, the authors recommend that further research be conducted to explore the potential of drones in healthcare, particularly in low- and middle-income countries where access to healthcare is often limited.

In summary, this review paper has provided an insightful exploration of research articles that center around the utilization of UAVs for emergency and healthcare purposes. It is evident that the most prevalent gaps in the existing literature revolve around the **regulatory frameworks governing operations**, the **level of social acceptance within communities**, **the limited real-world deployment scenarios**, and various **technical challenges encountered during implementation**. However, a notable and promising discovery stemming from these studies is the potential of UAVs to significantly enhance response times and improve the overall effectiveness of emergency situations when compared to traditional emergency response systems.

Despite the merit of the existing review papers, each one has limitations that could be addressed in a comprehensive review work. Upon analysing these review papers, some notable gaps emerged:

- **Lack of concerns regarding technology acceptance**: One noted gap in most of the papers ([Stephan et al., 2022],[Lim et al., 2022], [Zailani et al., 2020], [Robakowska et al., 2022b], [Wang et al., 2021], [Zailani et al., 2021b], [Bhatt et al., 2018], [Sanz-Martos et al., 2022], [Daud et al., 2022], [Roberts et al., 2023a], [Kucharczyk and Hugenholtz, 2021], [Hiebert et al., 2020], [Rosser Jr et al., 2018a], [Kerle et al., 2019], [Carrillo-Larco et al., 2018]) is limited attention to the social acceptance of the technology discussed. It is essential to explore how these innovations are perceived and embraced by society, and this can significantly impact their adoption.

- **Absence of real-word use cases**: Another significant gap in most of the papers ([Stephan et al., 2022],[Lim et al., 2022], [Zailani et al., 2020], [Robakowska et al., 2022b], [Wang et al., 2021], [Zailani et al., 2021b], [Bhatt et al., 2018], [Sanz-Martos et al., 2022], [Daud et al., 2022], [Roberts et al., 2023a], [Kucharczyk and Hugenholtz, 2021], [Hiebert et al., 2020],[Rosser Jr et al., 2018a],[Kerle et al., 2019], [Carrillo-Larco et al., 2018]) is the lack of emphasis on real-world use cases and implementations. Many of the reviewed papers may discuss theoretical concepts or prototypes, but there is often a shortage of insights into practical deployment and the challenges faced during the actual implementation of these healthcare technologies. .

- **Rural vs. Urban discrepancy**: In some papers ([Zailani et al., 2020], [Wang et al., 2021], [Zailani et al., 2021b], [Sanz-Martos et al., 2022], [Kucharczyk and Hugenholtz, 2021], [Hiebert et al., 2020], [Kerle et al., 2019]), the focus

is more on the rural healthcare use cases. Given the unique challenges and dynamics of urban healthcare, it is crucial to address this imbalance and explore how technology can be tailored to meet the specific needs of urban areas .

- **Lack of specific application focus**: Many of the reviewed papers ([Stephan et al., 2022], [Zailani et al., 2020],[Robakowska et al., 2022b],[Zailani et al., 2021b],[Bhatt et al., 2018],[Sanz-Martos et al., 2022],[Kerle et al., 2019],[Carrillo-Larco et al., 2018]) lack a specific focus on applications within healthcare and emergency management. It would be beneficial to explore particular use cases, such as telemedicine and medical supply delivery. to provide more targeted insights into these domains.
- **Out-of-date reviews**: Another gap observed is the prevalence of outdated or non-contemporary reviews [Bhatt et al., 2018], [Rosser Jr et al., 2018a], [Kerle et al., 2019], [Carrillo-Larco et al., 2018]. In the rapidly evolving healthcare field, particularly in emerging use cases, it is imperative to have up-to-date and current literature syntheses. Many of the reviewed papers do not capture the recent developments and innovations in the field, which can prevent the relevance and applicability of their findings.

3.6 Data extraction and synthesis of related papers

In this section, we conduct a comprehensive analysis of research papers that explore the applications of UAVs in healthcare and emergency services. Our dataset consists of a total of 170 papers, which were found through a two-step process. Initially, we collected a collection of papers by extracting references from previously analyzed review articles, resulting in a set of 130 unique papers after eliminating duplicates. Subsequently, to ensure inclusively, we conducted an additional search for new publications that had not been covered in the earlier reviews. This supplementary search resulted in 40 additional papers, bringing the total number of papers in our analysis to 170.

After a thorough analysis of these papers, we categorized them into two main groups: i) **using UAVs in emergency management**, and ii) **using UAVs in healthcare services.**

The works using UAVs in emergency management can be divided into several distinct subcategories, namely: **Search and Rescue**, **Disaster Monitoring**, **Damage Assessment and Mapping**, **Situational Awareness and Evacuation**, as well as **AED**. Furthermore, within the healthcare services domain, the emphasis is placed on the subsequent applications: **Delivery of Medical Supplies**, **Telemedicine**, **Hospital Internal Deliveries**, and **Collaboration with Robotic arms**.

The following sections will present the papers of each subcategory in detail. It will also provide a list of the different drone models and simulators used for testing in the analyzed papers. Additionally, it will discuss the requirements and challenges associated with using drones in emergency management and healthcare services. ultimately, it will present a statistical analysis of related work.

3.6.1 UAVs in Emergency Management

UAVs have proven to be invaluable tools in disaster and emergency management services. These versatile devices play a crucial role in enhancing response efforts, mitigating risks, and facilitating efficient recovery processes [Restas, 2015]. They enable quick and comprehensive visual assessments of disaster-stricken areas, providing real-time imagery and data to response teams [Baeck et al., 2019]. This data assists in establishing an accurate overview of the extent of damage, infrastructure integrity, and potential hazards, thereby aiding in effective decision-making [Kim et al., 2016]. UAVs equipped with thermal imaging cameras and sensors are pivotal in locating survivors in hazardous environments. They can efficiently cover large areas and provide live feeds to rescue teams, expediting the search and rescue process. Moreover, UAVs can serve as communication relays in areas where traditional infrastructure is disrupted [Popescu et al., 2020]. They can establish temporary communication networks, enabling communication between responders and affected populations [Duo et al., 2018]. UAVs are ideal for surveying dangerous environments, such as chemical spill sites or nuclear disaster areas, where human entry is risky. They can gather data on hazardous substances and assist in planning containment strategies. UAVs equipped with high-resolution cameras and LiDAR technology can rapidly generate detailed maps of disaster-affected regions. These maps aid in understanding terrain changes, damage patterns, and resource allocation [Seguin et al., 2018]. Numerous case studies underscore the efficacy of UAVs in disaster and emergency management. For instance, [Lin et al., 2017] demonstrated the utility of UAVs in assessing earthquake damage and post-earthquake displacement. Additionally, Harrison et al. (2018) highlighted the effectiveness of UAVs in search and rescue operations during forest fires. Overall, UAVs have emerged as essential assets in disaster and emergency management [Abrahamsen, 2015]. Their ability to provide real-time data, conduct rapid assessments, and perform critical tasks in hazardous environments has transformed response strategies. As UAV technology continues to advance, their role in disaster management is likely to expand further, aiding in saving lives and minimizing the impact of catastrophes[Connor et al., 2020]. Table 3.2 lists articles that concentrate on the implementation of UAVs in the area of emergency management.

UAVs in Search and Rescue

In this domain, UAVs are employed to aid in locating and rescuing individuals in emergency situations. These unmanned aerial vehicles can efficiently survey vast or hard-to-reach areas, providing real-time visual data to rescue teams, enabling them to identify missing persons, survivors, or assess disaster-stricken areas [Waheed et al., 2023]. UAVs equipped with thermal imaging and high-resolution cameras enhance search capabilities during natural disasters, wilderness rescue operations, and urban search missions. They significantly reduce search times and facilitate prompt and effective responses, thereby contributing to saving lives and improving the efficiency of search and rescue operations [Zolich et al., 2022].

Table 3.2: UAVs in Emergency Management

Application Domain	Phase	References
Damage Assessment and Mapping	-	[Li and Tang, 2018], [Sánchez Agüero et al., 2022]
	Preparedness	[Al Zayer et al., 2016]
	Response	[Rottondi et al., 2021], [Ulfa and Sartohadi, 2019], [Giordan et al., 2015], [Wang et al., 2018], [Connor et al., 2020], [Sugita et al., 2020], [Nex et al., 2019], [Coutinho and Boukerche, 2022], [Diao et al., 2022], [Tran et al., 2020], [Alnoman, 2022], [Schwartz et al., 2009], [Hardy et al., 2017], [Zwgliski, 2020], [Hashemi-Beni et al., 2018], [Kim et al., 2019], [Restas, 2015], [Boccardo et al., 2015], [Duo et al., 2018], [Watson et al., 2019], [Shrestha et al., 2021], [Rosser Jr et al., 2018b], [Liang et al., 2022]
Situational Awareness and Evacuation	Preparedness	[Urbanová et al., 2017], [Baeck et al., 2019], [Ozkan and Kilic, 2023]
Disaster Monitoring	-	[Yeh and Chuang, 2020], [Capolupo et al., 2015], [Kumar et al., 2022], [Ge et al., 2019], [Dasdemir et al., 2022]
	Mitigation	[Luo et al., 2020]
	Mitigation, Preparedness	[Hung et al., 2019]
	Preparedness	[Chang et al., 2020]
	Response	[Barnas et al., 2019], [Bejiga et al., 2017], [Lewis, 2007], [Al-Rawabdeh et al., 2017]
	Response, Recovery	[Seguin et al., 2018], [Fernandez Galarreta et al., 2015], [Lin et al., 2017]
Search and Rescue	-	[Póka et al., 2017], [Zheng et al., 2019], [Popescu et al., 2020], [Karaca et al., 2018], [Yamazaki et al., 2020], [Alsamhi et al., 2022]
	Response	[Tunio and Wróblewski, 2022], [Abrahamsen, 2015], [Lygouras et al., 2019], [Meshcheryakov et al., 2019], [Waheed et al., 2023], [Dorn et al., 2022], [Zolich et al., 2022], [Tatham, 2009], [Sandvik et al., 2017], [Scott-Smith, 2016], [Betts and Bloom, 2014],[Sheather et al., 2016] ,[Soesilo et al., 2016], [Wang, 2019], [Wang, 2020a], [Wang, 2020b], [Tatsidou et al., 2019],[Al-Naji et al., 2019], [Clark et al., 2018],[Mardell et al., 2014], [Jain et al., 2018]
AED Delivery	Response	[Claesson et al., 2016],[Cheskes et al., 2020], [Baldi et al., 2021], [Drennan et al., 2014], [Gino et al., 2022], [Kozio and Sobczyk, 2022a], [Su et al., 2022], [Sanfridsson et al., 2019], [Rosamond et al., 2020a], [Zègre-Hemsey et al., 2020], [Sedig et al., 2020], [Chu et al., 2021], [Derkenne et al., 2021], [Bauer et al., 2021a], [Baumgarten et al., 2022], [Claesson et al., 2017a], [Schierbeck et al., 2022], [Schierbeck et al., 2021], [Ryan, 2021], [Rees et al., 2021], [Mackle et al., 2020], [Pulver et al., 2016a], [Pulver and Wei, 2018], [Bogle et al., 2019], [Lancaster and Herrmann, 2020], [Starks et al., 2020b], [Starks et al., 2020a], [Smith et al., 2017], [Kaneko et al., 2018], [Lim et al., 2020], [Claesson et al., 2017b], [Pulver et al., 2016b], [Boutilier et al., 2017], [Yakushiji et al., 2020], [Choi et al., 2021b], [Bauer et al., 2021b], [Smith, 2022], [Kim et al., 2021], [Starks et al., 2020c], [Rosamond et al., 2020b], [Dayananda et al., 2017], [Pulver et al., 2016c], [Roberts et al., 2023b], [Duggal et al., 2023], [Kolawole and Hunukumbure, 2022], [Choi et al., 2021a], [Laksham, 2019]

UAVs in Disaster Monitoring

UAVs play a pivotal role in providing real-time data that aid in monitoring and assessing the aftermath of natural calamities [Luo et al., 2020]. this device by Equipped with advanced sensors and cameras, can capture detailed imagery, detect changes in terrain, and monitor the evolution of disaster situation. This real-time data allows decision-makers to gain crucial insights into the extent of damage, resource distribution, and population movement, enabling them to formulate targeted and effective response strategies [Chang et al., 2020]. Whether it's tracking the spread of wildfires, assessing floodwater levels, or evaluating structural damages post-earthquakes, UAVs offer an agile and efficient means to monitor disasters and make informed decisions that mitigate risks and enhance overall disaster management efforts [Bejiga et al., 2017]. As technological

advancements continue to improve UAV capabilities, their role in disaster monitoring is poised to expand further. their ability to swiftly cover vast areas, access hard-to-reach locations, and provide up-to-the-minute visual data positions make them as valuable assets in disaster management strategies [Hung et al., 2019]. UAVs have become integral in the modern toolkit for disaster monitoring, contributing to improved preparedness and response in the face of unforeseen crises from facilitating early warning systems to aiding in post-disaster recovery [Barnas et al., 2019].

UAVs in Damage Assessment and Mapping

UAVs provide rapid and comprehensive visual data that aid in evaluating the extent of destruction with unprecedented accuracy [Zwgliski, 2020]. UAVs capture detailed imagery from vantage points that may be challenging to access otherwise this enables responders to quickly assess the impact of disasters [Hashemi-Beni et al., 2018]. Furthermore, UAVs offer the advantage of remote damage assessment in hazardous environments, where human access might be restricted due to safety concerns [Kim et al., 2019]. In situations involving chemical spills, nuclear accidents, or collapsed structures, UAVs equipped with specialized sensors can collect critical information without endangering human lives. The data collected by UAVs facilitates not only the quantification of physical damage but also the assessment of potential risks and hazards, contributing to informed decision-making and effective disaster response strategies. As UAV technology continues to evolve, their role in damage assessment remains paramount, enhancing the efficiency and accuracy of post-disaster evaluations and supporting resilient recovery efforts [Duo et al., 2018].

UAVs in Situational Awareness and Evacuation

Situational awareness allows decision-makers to formulate precise evacuation plans, allocate resources effectively, and coordinate rescue efforts in a more informed and timely manner. In evacuation procedures, UAVs offer significant advantages by assisting in locating and guiding individuals to safety. Thermal sensors and infrared cameras enable UAVs to identify heat signatures, helping locate trapped or stranded individuals who might be otherwise difficult to spot [Schwartz et al., 2009]. Additionally, UAVs can relay live video feeds to emergency command centers, enabling responders to remotely monitor evacuation routes, assess road conditions, and identify congested areas that require immediate attention. By providing real-time updates on the evolving situation, UAVs contribute to smoother evacuation processes, reducing response time and enhancing the overall safety of evacuees and emergency personnel alike.

UAVs in Automated External Defibrillators (AEDs)

In this domain, UAVs have emerged as promising solutions for the swift and efficient delivery of AED in emergency situations. AEDs are critical medical devices

used to treat sudden cardiac arrests, and their timely delivery can significantly increase the chances of survival [Claesson et al., 2016]. UAVs equipped with specialized compartments can transport AEDs to remote or densely populated areas where traditional response times might be delayed [Rosamond et al., 2020a], [Derkenne et al., 2021]. These drones can be programmed to navigate through obstacles and follow pre-planned routes, ensuring rapid delivery to the scene of an emergency. Their ability to overcome traffic congestion and geographical barriers makes UAVs invaluable in delivering AEDs within the crucial minutes that can make a life-saving difference [Starks et al., 2020a], [Mackle et al., 2020]

The integration of UAVs in AED delivery also addresses challenges posed by accessibility and response time variations. In urban areas with heavy traffic or in rural regions with limited medical infrastructure, UAVs offer a reliable means of reaching patients quickly [Claesson et al., 2017a]. Furthermore, advancements in drone technology, including precise navigation systems and payload release mechanisms, contribute to the accuracy and safety of AED delivery [Choi et al., 2021a]. Collaborative efforts between drone manufacturers, medical professionals, and regulatory authorities are essential to ensure the seamless integration of UAVs in AED delivery systems, ultimately enhancing emergency medical services and potentially saving countless lives [Starks et al., 2020b]. Table **??** depicts several articles that concentrate on this particular application domain.

3.6.2 UAVs in Healthcare Services

UAVs, are altering the landscape of healthcare services by offering some solutions that enhance accessibility, speed, and efficiency. One of the prominent applications of UAVs in healthcare is the transportation of medical supplies, such as medications, vaccines, and blood samples, to remote or inaccessible areas. These aerial vehicles can bypass challenging terrain and deliver essential supplies promptly, bridging gaps in healthcare delivery and ensuring that patients receive critical treatments in a timely manner. The use of UAVs not only accelerates response times but also has the potential to save lives, particularly in emergencies where swift medical intervention is paramount [Washington, 2018].

Additionally, UAVs are contributing to the improvement of diagnostic and monitoring processes. Equipped with advanced imaging technologies, UAVs can assist in remote patient assessments by capturing high-resolution images or videos that can be transmitted to medical professionals for analysis. This capability is particularly valuable in scenarios where on-site medical expertise is limited, enabling healthcare providers to make informed decisions about patient care. Moreover, UAVs can play a role in disease surveillance, helping authorities monitor the spread of infections and contributing to early detection and containment efforts [Scott and Scott, 2017].

Furthermore, telemedicine and telehealth services are being enhanced by UAVs, enabling the delivery of medical advice and consultations to remote areas. UAVs equipped with communication equipment can establish temporary connectivity hubs, allowing patients to interact with healthcare professionals virtually. This in-

novative approach addresses the challenges of providing medical consultations in underserved regions and can contribute to better healthcare outcomes for individuals who lack easy access to medical facilities. As UAV technology evolves and regulatory frameworks adapt, the integration of UAVs into healthcare services has the potential to transform the way medical care is delivered, making it more inclusive, efficient, and effective [Knoblauch et al., 2019], [Jeyabalan et al., 2020]. Figure 3.4 depicts several articles that concentrate on the utilization of UAVs in healthcare services.

Table 3.3: UAVs in Healthcare Services

Application Domain	**Sub Domain**	**Phase**	**References**
Medical Supply Delivery	Blood	-	[Roberts et al., 2016], [McCarthy, 2007], [Gangwal et al., 2019], [Nisingizwe et al., 2022b], [Zailani et al., 2021a], [Glauser, 2018], [Nisingizwe et al., 2022a]
	Blood	Response	[Amukele et al., 2017], [Ackerman and Koziol, 2019]
	Drug	-	[Ye et al., 2019], [Beck et al., 2020]
	Drug	Response	[Ornato et al., 2020], [Tukel et al., 2020], [Mateen et al., 2020]
	Lab Sample	-	[Ochieng et al., 2020]
	-	-	[Balasingam, 2017], [Chowdhury et al., 2017], [Gera et al., 2021], [Shao et al., 2022], [Frith and Amiri, 2022], [Comtet and Johannessen, 2022], [Liu and Szirányi, 2022], [Kotlinski and Calkowska, 2022], [Martins et al., 2020], [Wang, 2021]
	-	Response	[Kozio and Sobczyk, 2022b], [Hachiya et al., 2022], [Mohammadiarvejeh and Hu, 2022], [John, 2022], [Gunaratne et al., 2022], [Koshta et al., 2022], [Park et al., 2022], [Robakowska et al., 2022a], [Liu and You, 2020]
	Organ	All	[Scalea et al., 2018]
	Vaccine	-	[Thiels et al., 2015], [Haidari et al., 2016], [Benayad et al., 2022], [Qassab and Ibrahim, 2022], [Van Tilburg, 2017]
Telemedicine	-	-	[Eichleay et al., 2016], [Subbarao and Cooper Jr, 2015], [Knoblauch et al., 2019], [Washington, 2018], [Scott and Scott, 2017], [Hanchate et al., 2017], [Jeyabalan et al., 2020], [Li et al., 2021],
Hospital Delivery	-	-	[Sharma et al., 2023], [Otero Arenzana et al., 2020]
Robotic Arms	-	-	[Kim et al., 2016], [Munawar et al., 2022],

UAVs in Medical Supply Delivery

In regions with limited infrastructure or during emergency situations, UAVs offer the potential to overcome logistical challenges and deliver critical medical resources such as vaccines, medications, and diagnostic equipment [Martins et al., 2020]. Equipped with GPS navigation systems and payload compartments, drones can navigate complex terrains and deliver supplies swiftly, often outpacing traditional ground transportation methods. This capability is particularly vital during

health crises or disaster scenarios, where timely delivery of medical essentials can significantly impact patient outcomes and public health [Wang, 2021]. The use of UAVs in medical supply delivery not only expedites the transportation process but also reduces the risk of pollution and infection transmission. By bypassing traditional transportation networks and minimizing human interactions, UAVs contribute to maintaining the integrity of medical supplies and safeguarding the health of both recipients and delivery personnel. As UAV technology continues to evolve and regulatory frameworks adapt, the integration of drones in medical supply chains holds the promise of enhancing healthcare delivery and resilience, particularly in times of crisis [Liu and You, 2020].

UAVs in Telemedicine

UAVs are transforming the landscape of telemedicine by offering innovative solutions to bridge geographical gaps and provide remote medical care. These aerial platforms are being harnessed to deliver medical supplies, diagnostics, and even tele-consultations to areas with limited healthcare access [Subbarao and Cooper Jr, 2015]. Moreover, UAVs equipped with telemedicine equipment enable real-time communication between healthcare providers and patients, allowing remote consultations and medical guidance, thereby extending the reach of healthcare services beyond physical barriers [Rosser Jr et al., 2018b]. By integrating UAVs into telemedicine networks, healthcare professionals can remotely diagnose and monitor patients, thereby enhancing patient outcomes and reducing the need for patients to travel long distances to access medical facilities. As regulations and technology continue to evolve, UAVs hold the potential to revolutionize telemedicine by providing timely and effective medical interventions to underserved populations, ultimately contributing to improved healthcare equity and outcomes [Nisingizwe et al., 2022a].

UAVs in Hospital Internal Delivery

UAVs are increasingly finding innovative applications within hospital settings, offering improved efficiency and resource management. In the healthcare sector, UAVs play a significant role in enhancing logistics and supply chain operations. They can swiftly transport medical supplies, such as medications, blood samples, and even organs, between different hospital departments or health centers. By bypassing ground transportation challenges and traffic congestion, UAVs ensure that critical items reach their destinations rapidly, potentially saving lives and optimizing patient care[Sharma et al., 2023]. As UAV technology continues to evolve, its integration with hospital workflows holds the promise of streamlining operations, reducing response times, and expanding the reach of medical services, ultimately contributing to more efficient and effective patient care [Krey and Seiler, 2019b].

UAVs in Collaboration with Robotic Arms

UAVs are extending their capabilities beyond traditional aerial tasks to collaborate with robotic arms, creating a powerful combination that holds immense potential in various fields. By integrating robotic arms onto UAVs, these systems can accomplish tasks that were once challenging or impossible. In industries like construction and infrastructure maintenance, UAVs equipped with robotic arms can carry out intricate tasks such as inspecting hard-to-reach areas, performing repairs, or assembling structures. This fusion of aerial mobility and precise manipulation enables a new level of efficiency and accuracy, reducing the need for risky human intervention and enhancing overall operational capabilities [of Seville, 2017].

The synergy between UAVs and robotic arms is particularly promising in disaster response scenarios. Equipped with robotic arms, UAVs can be used for search and rescue missions, remotely manipulating objects or debris to locate survivors in hazardous environments. Additionally, these systems can be deployed to deliver aid and supplies to inaccessible or dangerous locations, making them invaluable assets in post-disaster recovery efforts. As UAV and robotics technologies continue to advance, their integration holds the potential to transform industries and redefine the boundaries of what is achievable in aerial and ground-based operations, ushering in a new era of innovation and efficiency [W et al., 2022].

3.6.3 UAV Models and Simulators

Table 3.4 provides a list of UAV models and simulators (if applicable) used for testing in the analyzed papers.

3.6.4 UAVs Requirements and Challenges in Emergency Management and Healthcare Services

UAVs have become essential assets in emergency response due to their ability to rapidly assess and analyze affected areas. Despite their potential, UAVs in emergency response management face challenges such as regulatory obstacles, airspace density, and limited resistance. Furthermore, Integrating UAVs into existing emergency response systems requires coordination with aviation authorities to ensure safe and regulated operations. Crowded airspace can prevent drone operations that creates the needs for development of airspace management systems that accommodate both manned and unmanned aircraft. Lastly, the limited flight time of UAVs can hinder prolonged monitoring or assessment missions, demanding innovative solutions to extend flight duration [Ozkan and Kilic, 2023].

In healthcare, Key requirements include the establishment of secure communication networks for real-time tracking and monitoring of UAVs carrying critical medical supplies [Ge et al., 2019]. Additionally, medical payload optimization and temperature control systems are necessary to ensure the safe transportation

Table 3.4: UAV Models and Simulators Used in the Analyzed Papers

Reference	UAV Model	Simulation
[Claesson et al., 2017a], [Lim et al., 2020]	8-Rotor Drone	-
[Al Zayer et al., 2016]	Bebop Drones	-
[Beck et al., 2020]	Clogworks Dark Matter HX	-
[Luo et al., 2020]	DJI	-
[Zailani et al., 2021a]	DJI M600	V-REP
[Zheng et al., 2019]	DJI Mavic 2	-
[Urbanová et al., 2017],[Al-Rawabdeh et al., 2017]	DJI Phantom 2	-
[Watson et al., 2019], [Yeh and Chuang, 2020],[Ulfa and Sartohadi, 2019],[Yamazaki et al., 2020]	DJI Phantom 4 Pro	-
[Claesson et al., 2017b]	DJI S1000	PX4 SITL
[Subbarao and Cooper Jr, 2015]	DJI S900	-
[Tunio and Wróblewski, 2022]	DJIM600 Pro	-
[Sanfridsson et al., 2019]	Flirtey's Eagle	-
[Yakushiji et al., 2020]	M1000	-
[Sheather et al., 2016]	UX5	-
[Amukele et al., 2017], [Gangwal et al., 2019], [Glauser, 2018]	Zipline	-
[Alsamhi et al., 2022]	-	OPNET-14.5
[Martins et al., 2020]	-	NS-2

of sensitive medications, vaccines, and organs. Collaboration between healthcare institutions, regulatory bodies, and UAV manufacturers is crucial to developing standardized protocols and procedures for medical supply delivery. UAV deployment in healthcare faces challenges such as regulatory compliance, safety concerns, and public acceptance [Robakowska et al., 2022b]. Regulatory frameworks must be developed to ensure compliance with aviation standards while addressing specific healthcare needs. Safety measures, such as collision avoidance systems and geofencing, are essential to prevent accidents and protect both UAVs and people on the ground. Overcoming public concerns about privacy, noise pollution, and UAV reliability also plays a vital role in developing the acceptance of drone technology in healthcare [Munawar et al., 2022].

Both emergency management and healthcare share executive challenges, such as interoperability, data security, and technological advancements. Developing standardized data formats for information sharing and integration between UAVs and existing systems is crucial [Duggal et al., 2023]. Robust encryption and cy-

bersecurity measures are imperative to protect sensitive medical and emergency data. As UAV technology continues to evolve, advancements in battery life, payload capacity, and autonomous navigation will address many of the current limitations, enhancing their usability and impact in both sectors. In conclusion, UAVs hold vast promise in transforming emergency management and healthcare, provided that the requirements and challenges specific to each sector are effectively addressed. Collaborative efforts among various stakeholders, including government agencies, industry players, and regulatory bodies, will be pivotal in harnessing the full potential of UAVs for improved disaster response and healthcare logistics [Kolawole and Hunukumbure, 2022].

3.6.5 Statistical Analysis on Related Works

Having completed an exhaustive examination of 170 articles, certain outcomes were obtained. Figure 3.1 depicts the distribution of articles categorized by their application domains. As shown, the majority of the studies are focused on the delivery of AED and medical supplies.

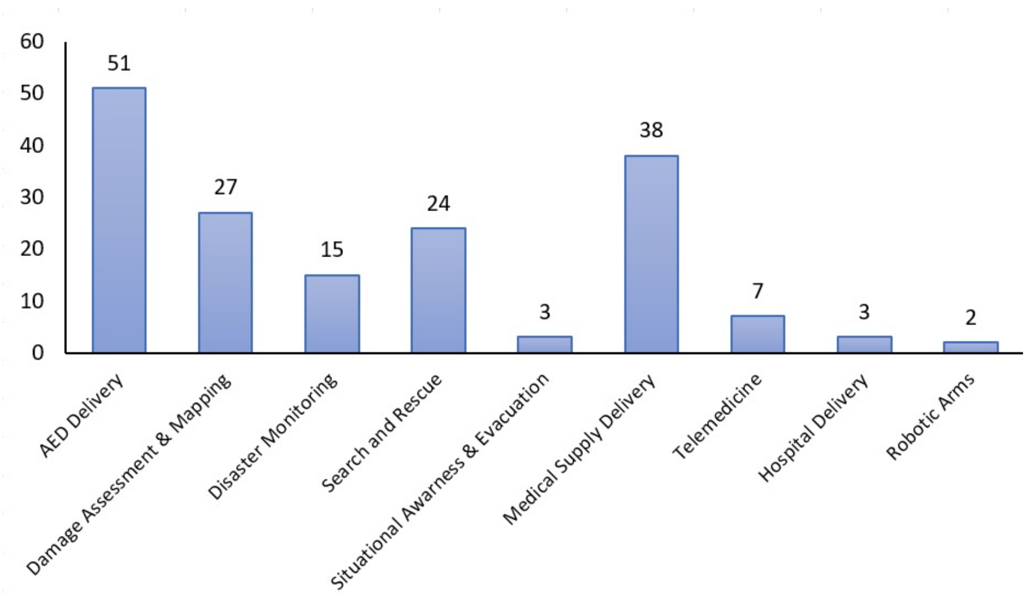

Figure 3.1: Distribution of the Articles According to Application Domain

Figure 3.2 presents the distribution of articles according to different phases of emergency management services. It is evident that most of the works are related to the response phase (about 66%).

Furthermore, we present the distribution of the papers across different geographical regions, specifically continents. As shown in Figure 3.3, a majority of the publications are attributed to Europe, followed by North America and Asia.

Additionally, Figure 3.4 provides an overview of articles distribution acrross European countries. As shown, most works belong to Germany, Sweden, and UK.

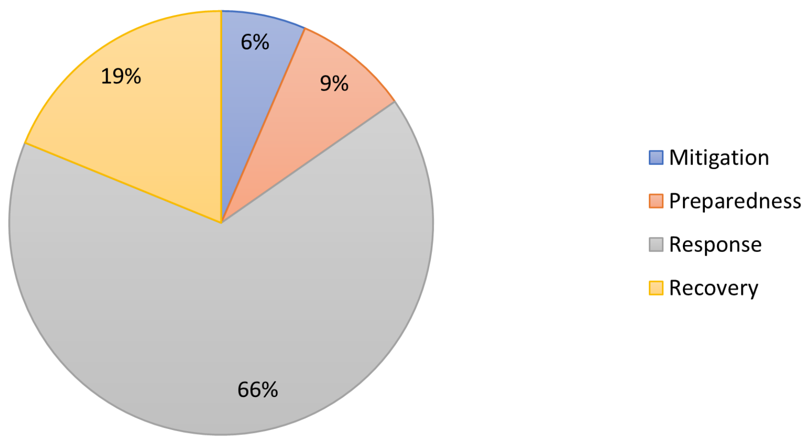

Figure 3.2: Distribution of the Articles According to Emergency Phases

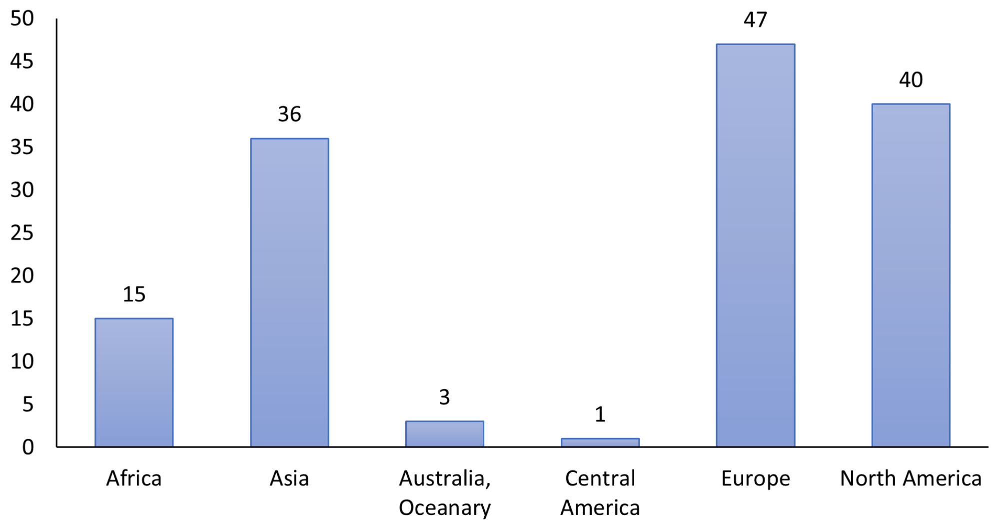

Figure 3.3: Distribution of the articles across different continents

3.7 Summary

Utilizing UAVs for health and emergency purposes presents some applications, simulations, and requirements. The applications range from disaster assessment and monitoring to search and rescue operations, significantly reducing response times and improving situational awareness. However, successful UAV integration requires careful consideration of technology acceptance, procedural adoption, and testing to ensure deployment, ultimately advancing the potential for UAVs to save lives and enhance healthcare services in emergency situations.

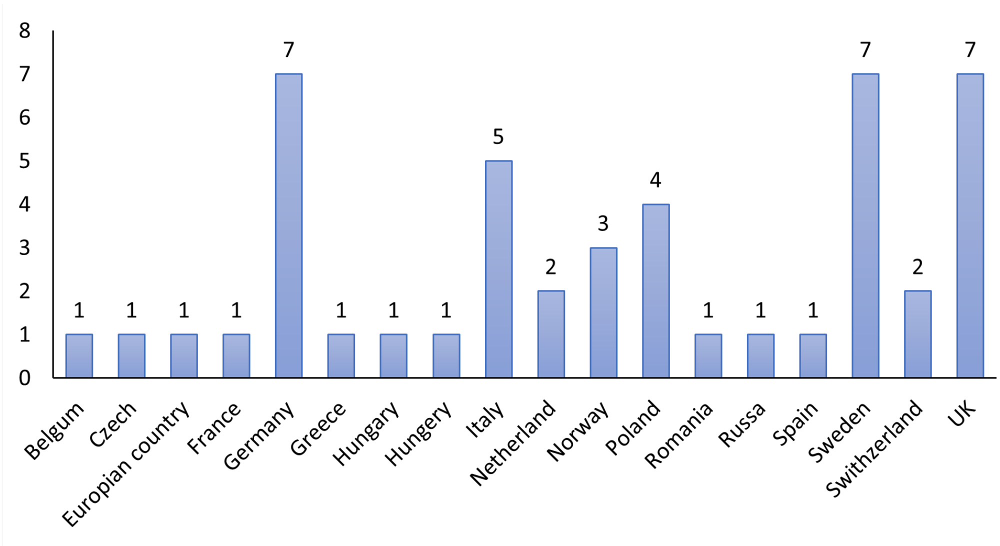

Figure 3.4: Distribution of articles across European countries

Chapter 4

Research Objective

In this chapter, we elaborate on the research objectives of the thesis. Taking into account the contextual background provided in the preceding chapters, our focus lies on addressing the challenges involved with using UAS, UAV in the context of Healthcare services and responding to medical emergencies. In general, this thesis aims to build solutions (e.g., guidelines, artifacts, framework) facilitating the smooth and safe integration of UAV in healthcare services. To achieve this goal, we have defined the following set of research objectives (ROs):

1. **RO1- Develop a mapping between various UAV models and diverse use cases within the healthcare and medical emergency services domains:**

   This entails a precise assessment of the UAVs' characteristics and their compatibility with healthcare needs, encompassing factors such as operation type, payload capacity, flight range, and required sensors. Furthermore, the established mapping should be validated considering the technical aspects within healthcare settings and the existing healthcare and emergency management regulations.

2. **RO2- Understanding the perception of stakeholders, in particular patients and healthcare professionals, regarding the utilization of UAVs in healthcare and medical emergency services:**

   By finding the viewpoints of these integral participants, this research aims to uncover insights into the acceptability, challenges, potential benefits, and concerns associated with utilizing UAVs to enhance the efficiency and effectiveness of healthcare services and medical emergency interventions. This exploration of stakeholder perceptions will provide valuable input for shaping future strategies, policies, and implementations related to UAV deployment in medical emergency scenarios, ultimately contributing to improved patient care and emergency response outcomes.

3. **RO3 - Develop a Framework for Integrating UAVs in Healthcare and Medical Emergency:**

This framework will include a systematic approach to address various aspects of UAV integration in healthcare. These aspects include UAV acceptance (i.e., by building a UAV acceptance model in healthcare and medical emergency based on the outcome of RO2), technical needs (i.e., identifying types of UAVs required in diverse use cases, required software and hardware, human-UAVs interaction based on the outcome of RO1), and procedural adaptation (i.e., redesign the existing healthcare workflows if necessary and ensuring regulatory compliance based on the outcome of RO1 and RO2). By addressing these fundamental aspects, the framework aims to provide healthcare services with a structured blueprint and guideline for effectively and safely harnessing the potential of UAVs.

4. **RO4 - Establish a platform to simulate and validate the formulated framework specially from technical point of view for UAVs integration in healthcare:**

   The objective is to create a platform for the assessment and validation of the developed framework for UAVs in healthcare. This platform will serve as a testing ground to simulate real-world scenarios, allowing for the thorough evaluation of the framework's effectiveness from technical point of view (e.g., whether the selected UAV model is appropriate for a given use case).. By establishing this platform, we can systematically analyze the framework's effectiveness, identify potential limitations, and refine its components to ensure its successful implementation and integration within healthcare systems. This validation process will provide valuable insights and data-driven improvements, ultimately enhancing the framework's readiness for real-world deployment and contributing to the advancement of UAV-enabled healthcare solutions.

In the next chapter, we will discuss the plan and steps we will take to achieve the above research objectives. This part is like a roadmap that helps us reach our target effectively. We will explain how our research or project will be conducted and what methods or techniques will be used to get the results we expect. It is like laying out the plan for a journey so that everyone understands how we will get to our destination.

Chapter 5

Approach and Methodology

This chapter outlines the approach and methodological strategy adopted to realize the research objectives defined in the previous chapter. The research approach is structured into four discrete phases, with each phase directly correlated to a specific research objective.

5.1 Phase 1: Develop a mapping between various UAV models and diverse use cases

To accomplish this phase, we need a deep understanding of both UAVs and healthcare and medical emergency services. The initial step will involve a literature review of existing research papers and technical documents that pertain to UAV classifications. This exploration will provide insights into the existing categorizations of UAVs based on factors such as size, range, payload capacity, and flight capabilities. By synthesizing this literature, a comprehensive classifying UAVs will be developed, capturing the diverse array of characteristics and functionalities that these vehicles encompass. Additionally, consultations with subject matter experts in the field of aviation, engineering, and application-specific domains will be undertaken to ensure a well-rounded perspective. Their insights will be instrumental in validating and enhancing the proposed UAV classification methodology, incorporating real-world considerations and practical implications. Ultimately, this classification will serve as a foundation for accurately categorizing UAVs based on their suitability for specified needs, aligning with the overarching objectives of the thesis.

The methodology we will use to figure out the special medical needs and use cases in which UAVs can be integrated will involve utilizing different methods, like interviews with healthcare professionals and studying the existing documents about medical emergency services. Initially, a literature review will be conducted, delving into existing research articles about the use of UAVs in healthcare and emergency services, medical journals, and authoritative books to establish a foundational understanding of the evolving landscape of medical drone applications. Moreover, the interview will facilitate the extraction of firsthand expe-

riential knowledge, expert opinions, and nuanced insights regarding the critical aspects that the UAV's design and capabilities must account for in a medical context.

5.2 Phase 2: Understanding the perception of stakeholders

The second crucial objective of this thesis is to gain a comprehensive understanding of the multifaceted concerns and perspectives held by key stakeholders, including patients and healthcare professionals, regarding the utilization of UAVs within the medical domain.

To initiate this endeavor, a mixed-methods approach will be adopted, integrating both qualitative and quantitative techniques. The qualitative aspect will involve conducting in-depth interviews [Hopf, 2004] with a diverse cross-section of stakeholders. By engaging in one-on-one interviews, it becomes possible to delve deeply into the thoughts, feelings, and concerns held by each stakeholder group. These interviews will be semi-structured, allowing for flexibility while ensuring that key themes related to UAV utilization are explored. Open-ended questions will be employed to encourage stakeholders to express their opinions freely and elucidate their apprehensions, expectations, and reservations about integrating UAVs into healthcare practices. The insights gathered from these interviews will be subjected to thorough qualitative analysis using techniques such as content analysis or thematic analysis. This will help in identifying recurring patterns, unique viewpoints, and common concerns across the stakeholder groups.

In parallel, the quantitative aspect of the methodology will entail the distribution of carefully designed surveys among a larger sample of stakeholders in healthcare services. These surveys will be constructed based on the themes and concerns identified during the qualitative phase. Likert scale [Batterton and & Hale, 2017] questions will measure the degree of agreement or disagreement with various statements related to UAV utilization. Additionally, open-ended questions will provide stakeholders with the opportunity to elaborate on their responses and offer delicate insights. The quantitative data collected through the surveys will be analyzed using statistical techniques, enabling the identification of trends, correlations, and potential variations in stakeholder opinions.

Furthermore, I intend to incorporate the TAM [Edwards et al., 2023], a well-established framework in the field. By integrating TAM into my research, I will not only explore stakeholder viewpoints but also analyze how they perceive and accept technology in the context of this study. This addition will provide valuable insights into the factors influencing technology adoption within the stakeholder group, ultimately contributing to a more holistic understanding of their perspectives and facilitating a more informed analysis of the research problem.

By employing this mixed-methods approach, a comprehensive and delicate understanding of stakeholder concerns pertaining to UAV deployment in healthcare settings will be attained. The integration of qualitative insights and quantitative

data will allow for a more robust interpretation of the diverse viewpoints held by patients, physicians, healthcare providers, and nurses. Ultimately, this methodology will serve to inform the development of strategies and interventions that address the identified concerns and ensure the successful integration of UAVs into the medical landscape while prioritizing the needs and perspectives of all stakeholders involved.

5.3 Phase 3: Develop an Integration Framework

To achieve this goal, a phased approach will be undertaken. Initially, a comprehensive assessment of the current regulatory landscape and legal framework governing UAVs is essential. This preliminary step involves a meticulous examination of the existing rules, regulations, and legislation that dictate UAV operations in urban airspace within the healthcare sector. This thorough regulatory assessment sets the stage for the subsequent formulation of a robust framework tailored explicitly for the integration of UAVs into specialized healthcare missions.

Following the assessment of existing regulations and the formulation of a framework including UAV classification, technical prerequisites, and medical requirements and regulation I start to create this plan using all the information gathered. This framework serves as a practical guide, showing the necessary steps for successfully incorporating UAVs into specialized healthcare missions.

5.4 Phase 4: Validate the established integration framework

The first step entails defining a set of performance metrics that comprehensively measure the framework's performance within the healthcare context. These metrics could include parameters such as response time, accuracy of medical deliveries, operational costs, and scalability, among others. This step is vital in establishing a quantifiable foundation upon which the framework's effectiveness can be objectively measured.

For instance, simulated medical emergency scenarios could be employed to assess the responsiveness and efficiency of the UAV framework in critical situations. By subjecting the framework to these scenarios, its strengths and limitations can be identified, providing insights into potential areas of improvement. Through careful observation and data collection, the framework's real-time impact on healthcare processes can be quantified, shedding light on its practical feasibility and potential benefits.

To make the evaluation more trustworthy, we can compare the UAV-enabled healthcare system with traditional methods or new technologies. This helps us understand the system's strengths and weaknesses better, so we can judge how well it works. Furthermore, feedback from healthcare professionals, stakehold-

ers, and end-users should be actively searched and included in the evaluation process. Their insights can provide valuable perspectives on usability, user-friendliness, and alignment with the actual needs of healthcare settings.

Recently, the Portugal government decided to integrate existing hospitals, hospital centers, and groups of health centers into the model of Local Health Units. This is one of the biggest reforms in the organization of the SNS since its creation, which seeks to respond to the increase in health and well-being needs of the population, associated with aging, the burden of disease, and their growing demands and expectations [portugal, 2023]. In light of this news, we will assess our developed framework within the healthcare institutions of Figueira da Foz, covering hospitals and health centers.

5.5 Work plan Activities

The research plan includes 5 tasks that are detailed below, and its scheduling is presented in Figure 5.1.

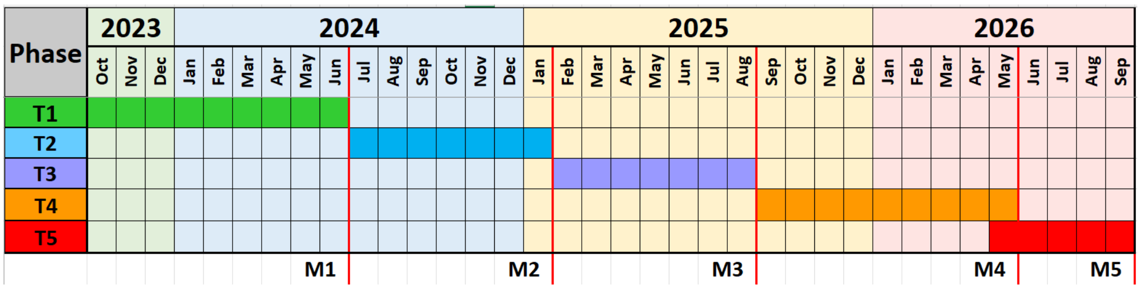

Figure 5.1: Gantt Chart of the phases to be completed in this research.

T1 The first goal is expected to take approximately ten months. At the end of this period, our aim is to submit a research paper with the main results.

T2 To reach our second goal, which involves finding out what stakeholders think about this project, we'll need about seven months of work. The survey results are planed to be submitted to a journal publication.

T3 To reach our third goal, which involves researching UAV regulations and creating a framework for UAV adoption. Considering an iterative approach to the framework development, with different artifacts (e.g. technical aspects, medical needs, regulation), we expect to publish two research publications.

T4 To achieve our fourth goal, which is to test the framework we've created, we'll need about nine months of time. After this period, we plan to submit a paper to a journal or conference.

T5 In conclusion, it will take approximately five months to complete the writing of the PhD thesis. During this time, we will work diligently to gather data, conduct research, analyze findings, and put together a comprehensive document that reflects the culmination of our academic journey and expertise.

5.6 Dissemination Strategy

Several journals and conferences have directed their attention towards topics and concerns that closely align with our research interests. This synergy provides an ideal platform for sharing our research outcomes with both the academic and industrial communities. By targeting these specific journals and conferences, we aim to foster meaningful exchanges of knowledge, insights, and potential collaborations. The details of these pertinent journals and conferences can be conveniently located in Table 5.1 identifies potential outlets to submit our research results. Through this strategic selection, we aspire to contribute to the ongoing dialogue within the academic and industrial spheres on the subjects of our investigation.

Table 5.1: Target conferences and journals to publish the results of this research.

Journal / Conference	**Publisher**	**Impact Fatctor**
The International Journal of Information Management (IJIM)	Elseveir	21.35
Transport Review	Taylor and Francis	11.134
IEEE Access	IEEE	4.342
Journal of Aerospace Information System	Aero Space Research Center	1.875
International Conference on Health and Social Care Information System And Technology (HCist)		
International Conference on Information Systems Development (ISD)		
The European Conference on Information Systems (ECIS)		

5.7 Summary

This chapter presented the design of our methodology and work plan to achieve the proposed research objectives. Subsequently, we establish key milestones that serve as checkpoints for monitoring the progression of our work, ensuring a seamless workflow and allowing the author to maintain a secure margin of progress. Furthermore, we expound upon our perspective regarding potential future publications.

Chapter 6

Conclusion

In conclusion, this proposal lays the foundation for an essential exploration into the integration of UAVs within the healthcare sector, with a particular focus on urban airspace in Portugal. The development of a comprehensive framework that encompasses UAV classification, medical needs, and regulatory considerations is a significant step towards realizing the potential benefits of UAVs in healthcare. This proposed framework seeks to bridge the gap between technology and healthcare needs, ultimately enhancing the quality and efficiency of healthcare services in urban Portugal.

The first foundation of our proposed framework involves the classification of UAVs. This step is essential in selecting the right UAVs for healthcare missions. By categorizing UAVs based on factors like payload capacity, range, and endurance, we can identify which UAV models are best suited for specific healthcare tasks. This classification ensures that the chosen UAVs can safely and effectively transport medical supplies, medications, and equipment in urban airspace.

The second crucial element is the consideration of medical requirements. Collaborating closely with healthcare professionals, we will pinpoint the precise healthcare tasks that UAVs can support. This includes the secure and timely delivery of medical essentials, assistance in telemedicine initiatives, and even monitoring patients in challenging urban environments. Our framework will account for factors such as temperature control and sterilization to guarantee the safe transport of medical materials.

The third important aspect is regulatory compliance. Adherence to existing aviation and healthcare regulations is vital to ensure safe UAV operations in urban airspace. Our framework will meticulously assess and navigate the complex regulatory landscape, providing guidance on how UAVs can seamlessly integrate into the healthcare sector while complying with evolving regulations.

By implementing this comprehensive framework, we aim to pave the way for the successful integration of UAVs into the healthcare services in Portugal's urban airspace. This initiative not only has the potential to enhance the efficiency of healthcare services but also contributes to improved patient care and timely medical interventions, ultimately benefiting the healthcare landscape in Portugal.

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Appendices

Appendix A

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